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LAND USE AND POLLUTION PATTERNS ON THE GREAT LAKES

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ABSTRACT

The focus of this investigation is to assess the utility of remote sensing techniques in the study of land use - water quality relationships in a west central Wisconsin test area. The following types of aerial imagery are evaluated for this purpose: high altitude (60,000 ft) color, color infrared, multispectral black and white, and thermal; low altitude (less than 5,000 ft) color infrared, multispectral black and white, thermal, and passive microwave. A non-imaging hand-held four band radiometer was also evaluated for utility in providing data on suspended sediment concentrations.

Land use analysis includes the development of mapping and quantification methods to obtain base line data for comparison to water quality variables. Suspended sediment loads in streams were determined from water samples and are related to land use differences and soil types in three major watersheds. A multiple correlation coefficient (R) of 0.85 was obtained for the relationship between the 0.6-0.7 micron incident and reflected radiation data from the hand-held radiometer and concurrent measurements of suspended solids in streams. Applications of the methods and base line data developed in this investigation include mapping and quantification of land use, input to watershed runoff models, the estimation of effects of land use changes on stream sedimentation, and the remote sensing of suspended sediment content of streams.

PREFACE

This report was prepared by Mr. Richard K. Haugen, Geographer, Dr. Harlan H. McKim, Research Soil Scientist and Mr. Thomas Marlar, Chief, Photo Services. The authors wish to express their appreciation to the following individuals for their considerable contributions to the report, especially land use mapping and measurement: Mr. P.J. Splett, Mr. Lawrence Gatto, Ms. Carolyn Merry, Mr. Michael Hutton, and SP4 Martha Greer. Dr. H. Huddleston, University of Wisconsin at Green Bay provided underflight stream temperature measurements on several occasions. Dr. A. O. Lind, University of Vermont provided assistance on analysis of the high altitude thermal imagery and stream color characteristics. The illustrations were done by Mrs. Eleanor Huke. This work was performed within the Earth Sciences Branch, USACRREL, Dr. D. M. Anderson, Chief, and as a part of the Corps of Engineers (CW) Remote Sensing Program, Mr. J. W. Jarman, Chief. USACRREL Cost Codes (Reimbursable): P5911 CC: 2 70 70 839 and P691100 CC: 3 70 70 926.

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INTRODUCTION

The Great Lakes represent one of the nation's most valuable resources and have been a major factor in the settlement and economic growth of the mid-continental area of both the United States and Canada. The lakes are utilized for many purposes, such as transportation, waste disposal, water supply, hydroelectric power production, and commercial fishing. The recreation industry is important both on the lakes and around the shorelines. A gradual deterioration in water quality caused by these uses has been documented (Beeton 1970), with Lakes Erie and Ontario showing the greatest amounts of pollution and eutrophication. Lake Michigan, the focus of the initial phase of this study, does not exhibit the advanced deterioration of the eastern lakes, but there are serious problem areas in Green Bay and at the southern end of the lake as well as indications of long-term deterioration in the open waters (Beeton 1970). The seriousness of this condition in Lake Michigan is emphasized because the water turnover rate is low compared to the eastern lakes, and most of the major streams which feed Lake Michigan are already polluted.

As land use patterns evolve, generally following a progression from forest to agriculture to urban or industrial uses, stream flow and water quality characteristics also change. The Corps of Engineers, along with its responsibility for the maintenance of inland navigable waterways, is concerned with the environmental impact of pollutants,

especially as they affect lakes and streams. Stream sedimentation, a form of pollution which can often be related to economic activity, is of particular interest in this investigation.

OBJECTIVES

This investigation examines the feasibility of using remote sensing methods to assess the effect of land use as it influences sediment loading in streams rapidly and economically on a regional scale.

To accomplish this task, these specific objectives were identified: 1) The acquisition and evaluation of a large variety of remote sensing imagery, 2) the development of techniques for mapping and quantification of land use patterns, 3) the assessment of the cost effectivenss of these mapping and measurement techniques, and 4) the collection and analysis of water quality samples for comparison to land use characteristics and correlation with signatures identifiable by remote sensing techniques.

APPROACH AND PROJECT HISTORY

This study was initiated in April, 1972. A field trip was taken in May of 1972 for an overview of the test area and to acquire data from state and federal agencies in Wisconsin. The initial phase of the study was primarily devoted to the aquisition of published data and the evaluation of a variety of imagery provided by NASA in September of 1972.

Considerable effort was devoted to experimentation with mapping techniques using two types of densitometry. The intent was to develop methods for the areal measurement of land use types directly from imagery. Using filtering and color infrared emulsions, some success was achieved

in differentiating USGS Land Use Classification Level I, but only where soil color was light. A system of densitometric measurement with hand drawn overlay maps was eventually developed. This technique provided the necessary data for subsequent comparisons with water quality parameters.

Two methods were used to extract from imagery water quality information that could be correlated to measurements done in the field. The first method was the development of a color classification for streams in the study area, based on a densitometric method was to quantify photographic stream color differences displayed in the 1972 high altitude Aero Ektachrome imagery. The results of this approach were not sufficiently consistent to be of practical value. During the 1974 missions, ground truth data on reflected and incident radiation in the ERTS MSS spectral bands was obtained. This method provided more reliable data and permitted significant correlation with measured concurrent suspended sediment loads for several major streams in the test area. These data were then compared to measurements of land use and soil types in the individual watersheds for analysis of regional relationships.

In July 1973, a chapter was prepared on Land Use Mapping for the Corps of Engineers Handbook, "Remote Sensing for Environmental Analysis" (Haugen and Splett, 1974). This was based on land use mapping procedures developed during the project and provides a practical discussion and guidelines for land use mapping. The utility of ERTS-1 and high altitude color infrared imagery were compared for land use mapping applications within the Corps of Engineers Missions.

Table 1. Summary of Project Milestones and Events

Milestones	CY72* 1	CY72* 2	CY72* 3	CY72* 4	CY73 1	CY73 2	CY73 3	CY73 4	CY74 1	CY74 2	CY74 3
Project Commencement		▲									
Acquisition of existing photographs and maps		━	━	━	━	━					
Literature review		━	━	━	━	━	━	━			
Imagery Acquisition											
NASA, RB-57, Photographic coverage		▲								▲▲	
NASA NP-3, Thermal scan					▲						
USACRREL, Cessna, Hassalblad & Ziess photography							▲			▲	
Field investigation		▲			▲		▲			▲	
Quarterly Management/Financial reports			▲	▲	▲	▲	▲	▲	▲	▲	
Interim Report to NASA								▲			
Imagery Analysis			━	━	━	━	━	━	━	━	
Thematic mapping				━	━	━	━	━	━	━	
Preliminary				━	━	━	━				
Final								━	━	━	
Presentations											
Annual Meeting, Northern New England Remote Sensing Group (U. Vt)								▲			
Corps of Engineer Remote Sensing Symposium, LBJ Space Center								▲			
Project Review at Office of Chief of Engineers					▲						
Northern Central Div., CE, Remote Sensing Symposium									▲		
Publication "Land Use Mapping" OCE Remote Sensing Handbook										▲	
Final Report (Draft) Submitted to OCE for review											▲

Remarks

* Calendar year divided into quarters

Papers and presentations related to or resulting from this project are as follows:

Papers

Preliminary Scientific Analysis Report "Land Use and Pollution Patterns on the Great Lakes", submitted to OCE-NASA, Dec. 1973.

Land Use Mapping, IN: Remote Sensing of the Environment, Chapt. 5, pp. 5-1 - 5-17, Office of the Chief of Engineers, Washington, D.C., 1974.

Presentations

Project review, Office of Chief of Engineers, Systems Analysis Branch, Washington, D.C., 9 March 1973.

Remote Sensing of Land Use and Aquatic Pollution, Annual Meeting of of Northern New England Remote Sensing Group, Oct. 1973.

Land Use and Pollution Patterns, Great Lakes, OCE Remote Sensing Symposium, 26-30 Nov. 1973, LBJ Spaceflight Center, Houston, Texas.

Report on Great Lakes Investigations, Remote Sensing Symposium, Central Div., C.E. Chicago, February 1974.

STUDY AREA

The Wisconsin shoreline of Lake Michigan, NASA Test Site 311 (Fig. 1) was selected for this investigation for several reasons: 1) The area is predominantly agricultural with relatively isolated concentrations of urban and industrial land use, so that the contributions to pollution levels of the basic land use types can be more readily assessed; 2) the general pollution of Lake Michigan is still low enough so that future benefits from identification of present and potential "trouble spots" can be realized; 3) the streams entering Lake Michigan from the Wisconsin shoreline are relatively short so that entire watershed areas can be mapped within about 50 miles of the shoreline.

Physical Setting

The test area lies within the Eastern Ridges and Lowlands physiographic subprovince of Wisconsin. The eastern portion is entirely underlain by the Niagara Cuesta limestone formation which forms the Door County Peninsula and extends to the southern boundary of Wisconsin, sloping gently toward Lake Michigan. The other major physiographic subprovince is the Lake Winnebago--Green Bay Lowland, a gently sloping plain which contains Lake Winnebago, the Fox River Valley, and a submerged portion forming Green Bay. The entire landscape of the test area has been extensively modified by Pleistocene glaciation, with glacial deposits forming most of the local relief which ranges up to 200 feet. The Lake Michigan shoreline is formed from tills and lacustrine sediments of

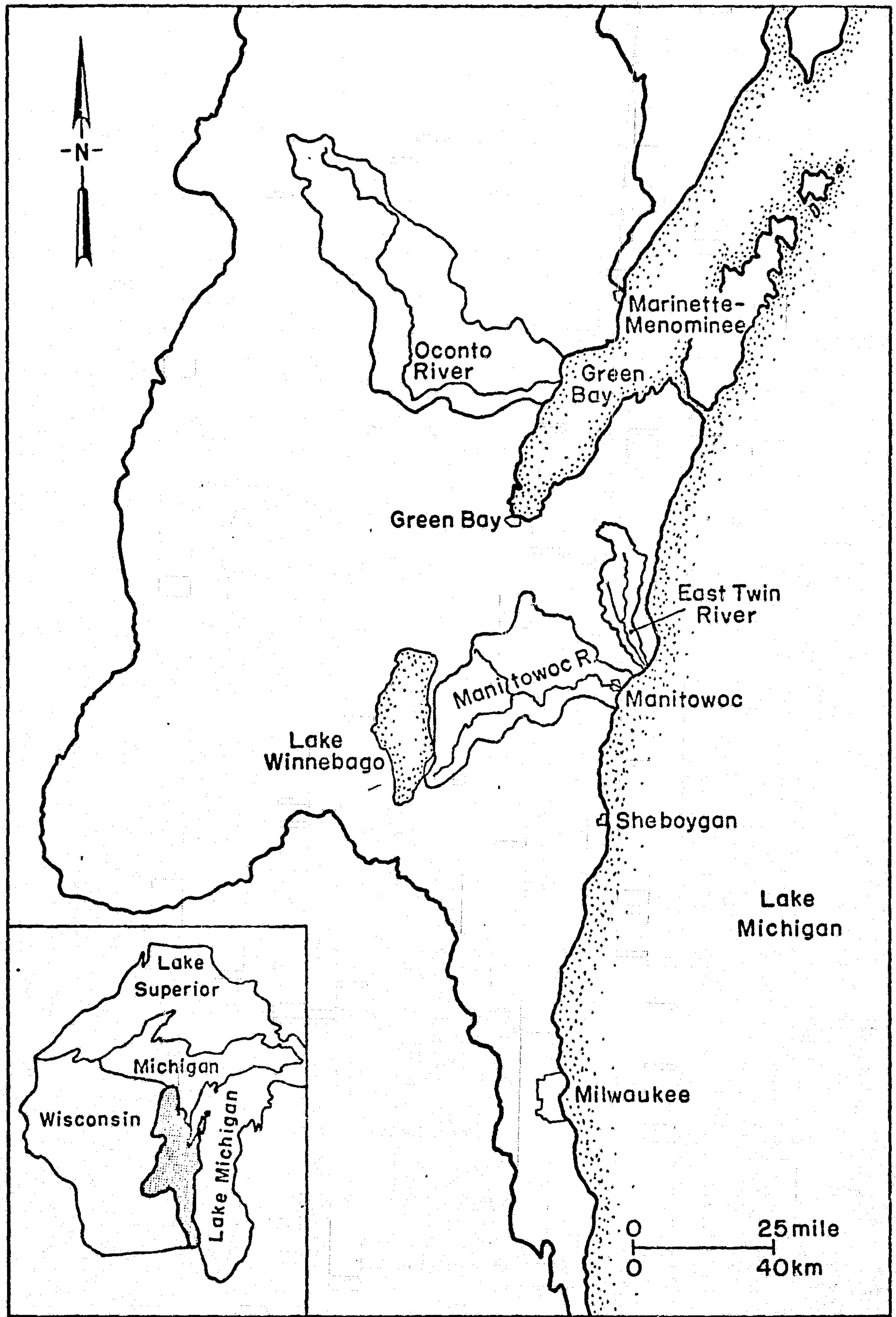


Figure 1. Study area and watershed boundary of Wisconsin rivers draining into Lake Michigan.

higher glacial lakes, which has resulted in wave-cut cliffs 100-120 feet high in much of the test area. Erosion of these unconsolidated materials continues at the present time, resulting in a large sediment load in the nearshore waters.

The major streams of the study area are the Fox, the Wolf, the Menominee, and Oconto which drain into Green Bay, and streams draining into Lake Michigan, which are, from north to south along the shoreline, the East and West Twin, Manitowoc and Sheboygan Rivers. The rivers draining directly into Lake Michigan do not have sources west of the Niagara Cuesta with the single exception of the Manitowoc, which is believed to have drained Lake Winnebago during glacial times. Many lakes dot the glacially modified landscape, few of them with an area exceeding 3,000 acres. Lake Winnebago, 215 square miles, is the largest lake in the state and was formed behind a morainal dam during glacial retreat.

Soil associations in the study area include the Northern and Eastern Sandy and Loamy Reddish Drift Uplands and Plains, Northern Silty Uplands and Plains, Northern Loamy Uplands and Plains, Northern Sandy Uplands and Plains, and Stream Bottom and Major Wetlands in the area between the Oconto and Fox Rivers. The major soil association in the East and West Twin and Manitowoc River Watersheds are the Soils of the Northern and Eastern Clayey and Loamy Reddish Drift Upland and Plains. Minor soil associations include well to poorly drained sandy soils and poorly drained depressional soils with some peats and mucks.

The climate of the test area is continental, with long and severe winters, especially in the north, and very warm summers. Lake Michigan modifies temperatures to some extent in a narrow belt bordering the lake, but the effect is minimized by the general easterly and southeasterly trend of most weather-system movements through the areas. The warming effects of Lake Michigan are, therefore, much less for eastern Wisconsin than for western Michigan.

January is the coldest month, with an average temperature ranging from 13°F in the north to 24°F in the south. During July, the warmest month, average temperatures range from 66° to 73°F north to south. The frost-free season ranges from 10 June to 30 August in the north to 25 April to 20 October in the south. The wettest months are May through September, and precipitation totals range from 29 to 33 inches, north to south. Snowfall ranges from 60 inches in the north to 30 inches in the south.

Weather conditions in eastern Wisconsin prior to and during aircraft missions and/or water sampling dates are indicated by temperature and precipitation data in Appendix I. Generally, the weather for the RB-57 flights had to be fair, with few clouds. Scattered rain showers preceded the flights in much of the test area. The 24 June 1974 NP-3 night time thermal scan was not completed due to heavy ground fog, and weather conditions during September and October 1973 resulted in two cancelled missions. Both flights were accomplished during May and June 1974, but with difficulty due to frequent cloudy conditions.

Cultural Setting

The population within the test area is in the neighborhood of 3,000,000. The largest population concentration is in and around Milwaukee, which is also the economic center of the area. Manufacturing is by far the largest employer within the test area, followed by agriculture, forestry, construction and mining. Over half of the northern part of the test area is in forest, and wood processing firms are a major part of the region's economy. Much of this industry is centered in the Fox River Valley. Mining activity includes extraction of clay, limestone, sand and gravel, together with some iron ore and granite in the north. The recreation industry is also important, particularly in the northern forested areas.

Agriculture is important throughout the area. Grain crops are dominant in the south, and vegetables, small fruits and horticultural specialties are raised in the central and northeast portions. Dairying, together with related processing industries, is important throughout the area. Some irrigation is practiced with specialty crops.

DOCUMENTED POLLUTION SOURCES IN THE STUDY AREA

There has been considerable activity in the areas of identification and control of aquatic pollution in eastern Wisconsin. Known major sources of pollution have been identified, and recommendations for remedial action have been made by the Wisconsin Department of Natural Resources. Three divisions of the U. S. Department of Agriculture, the Soil Conservation Service, the Economic Research Service, and the U. S.

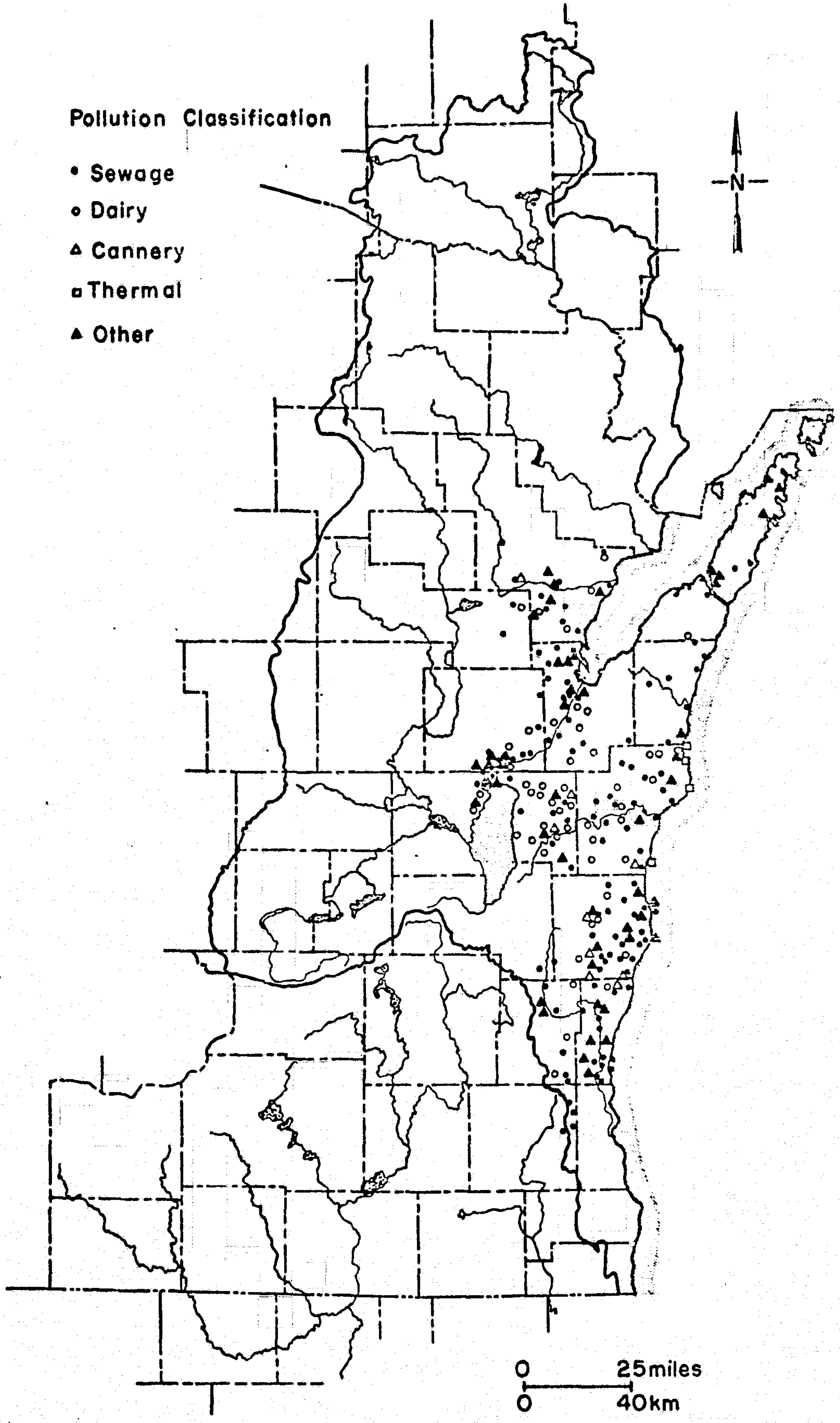


Figure 2. Documented aquatic pollution sources in the study area.

Forest Service, are engaged in a cooperative study of flooding and water management problems entitled the "Southeast Wisconsin River Basin Survey."

A map of known aquatic pollution sources (Fig. 2) was compiled from information gathered by the above agencies, especially the Wisconsin Department of Natural Resources, Environmental Protection Division. The point sources of pollution are mapped in five categories: 1) sewage, 2) dairy, 3) cannery, 4) thermal and 5) other types. As will be discussed in subsequent sections, few of these point sources are visible in the small scale photography acquired during Mission 205 or Mission 273.

The largest contributors to polluted waters are inadequate sewage treatment systems. This problem is not unique to the study area, but typifies other areas around the Great Lakes and many other areas of the United States. Most of the major cities have a sewage treatment plant, but many plants are working at greater capacities than they were designed to handle. Some smaller towns have no treatment plants, and insufficient and/or inadequate septic tanks contribute to the problem. Attempts are being made to rectify the situation and reduce the excessive amounts of phosphorus reaching the streams.

The dairy industry is one of the leading sources of income within the study area. As a result, many dairy-processing plants operate in the area, and in most cases their wastes reach streams with little or no treatment. In other instances, dairy wastes enter existing sewage-treatment plants, contributing to the overloading of some of them.

Vegetable and fruit production is an important occupation among some farmers in the area. Consequently there are several canneries that contribute wastes to streams. These wastes add various chemicals from washing operations, and increase the organic load to some extent.

There are a limited number of thermal pollution sources within the study area. These include electric power generating facilities and sewage treatment plants. The major sources of waste heat are two nuclear power plants, the 527,000-KW plant at Kewaunee and the 597,000-KW plant at Point Beach. These plants are located on Lake Michigan and use water directly from the lake for cooling.

The "other" category of point sources of pollution includes: paper-processing factories, which contribute chemical and organic wastes, industrial plating facilities, dairy farms and tanneries.

cilities, dairy farms and tanneries.

EVALUATION OF THE IMAGERY

Mission 205, 4 June 1972

The flight lines for the RB-57 photographic missions accomplished 4 June 1972 are indicated in Figure 3. During 1973, a low altitude thermal scan, Mission 235, Figure 4, was flown with coverage of the coastal portions of the test area along with the Fox River. An attempted second RB-57 overflight in September 1973 was aborted due to unfavorable weather conditions over the test area. The 1972 RB-57 coverage was repeated in 1974 during Missions 273 (3 and 7 May 1974) and 284 (12 June 1974). Separate flights of these missions were required to cover the

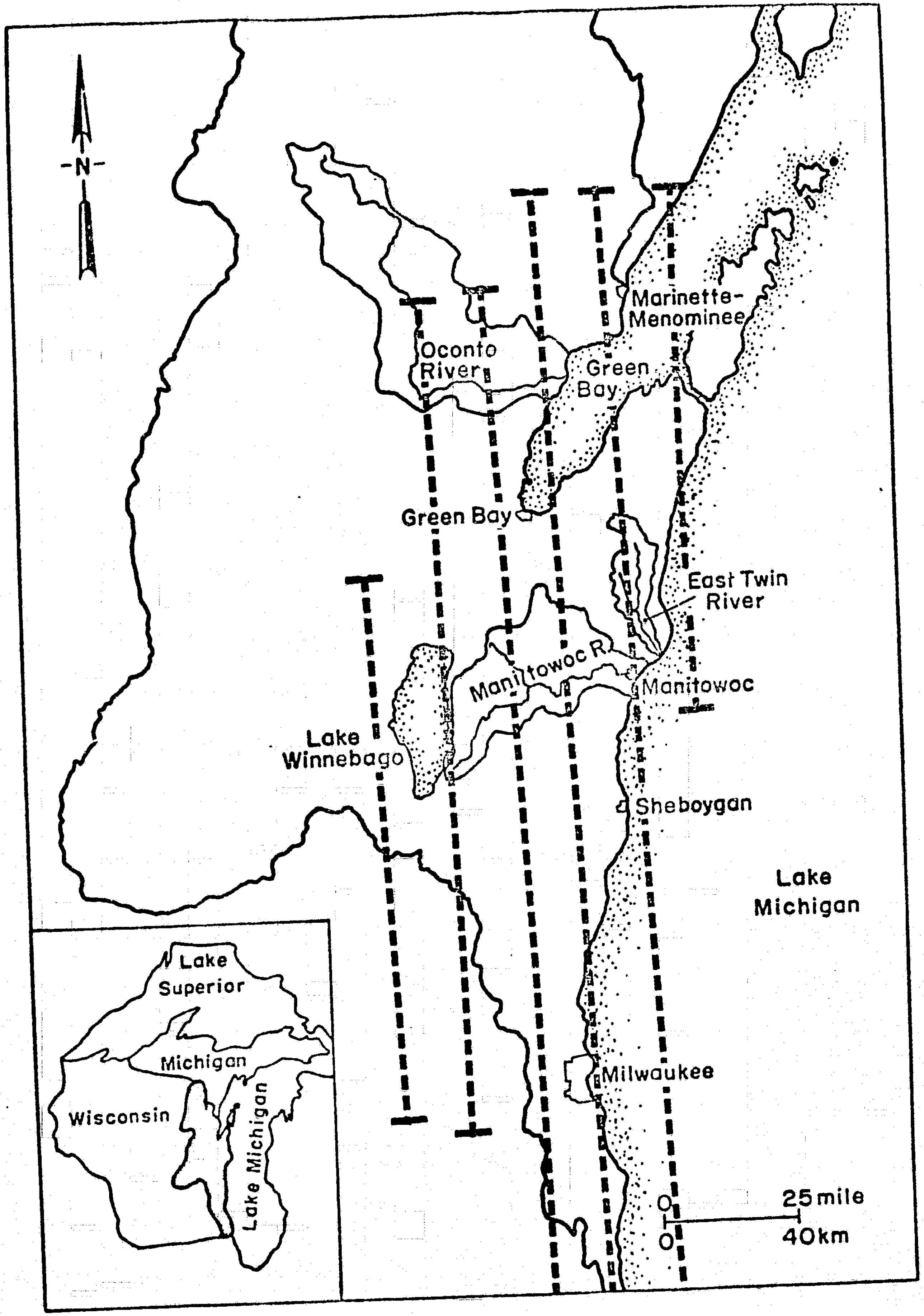


Figure 3. Generalized flight lines for RB-57 photographic missions.

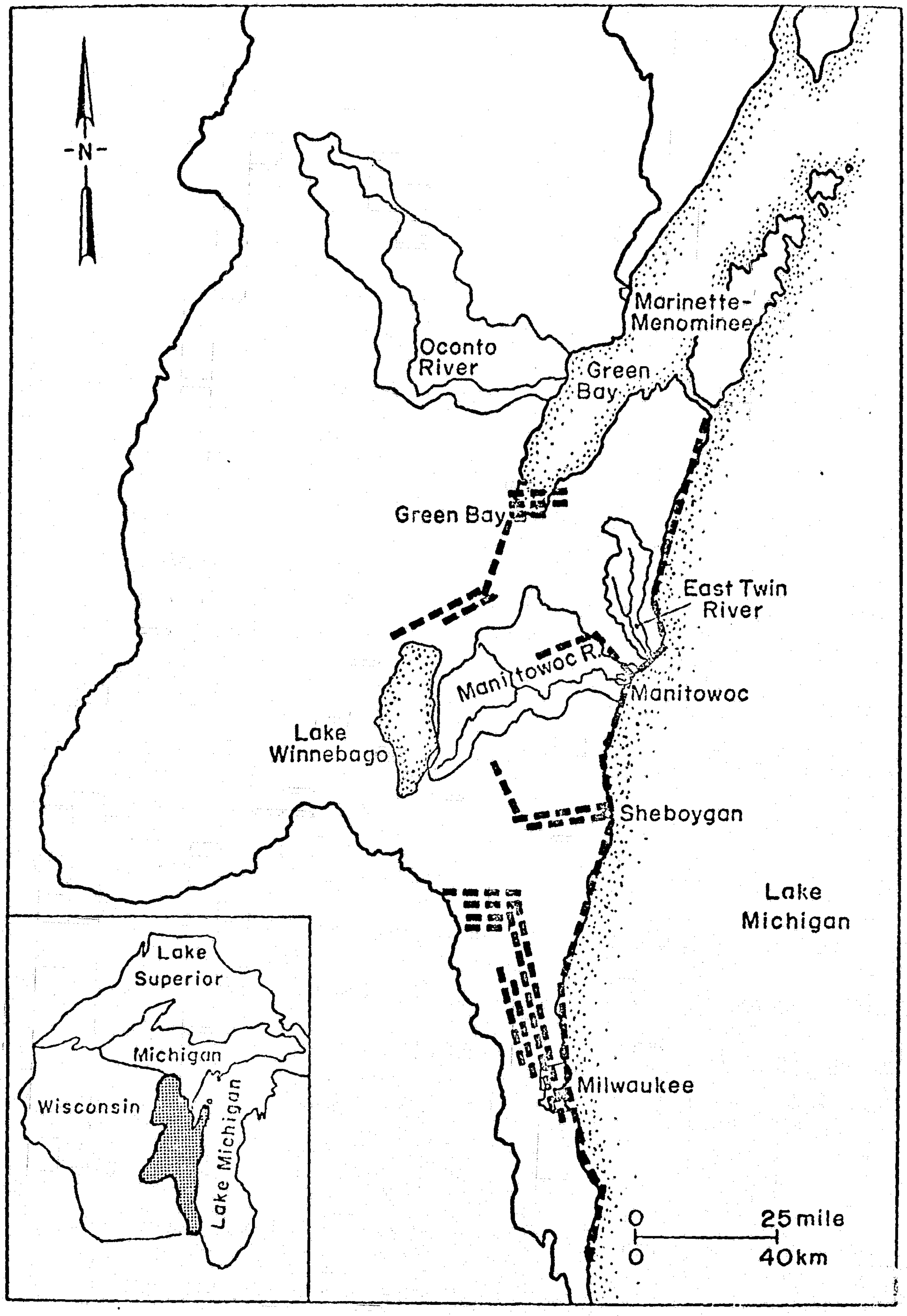


Figure 4. Flight lines for low altitude thermal scanning missions.

test area because of poor weather conditions. A second coverage with the NP-3 aircraft was also obtained on 31 May 1974, Mission 272 which included the Wisconsin coast, the Fox, Manitowoc and Sheboygan Rivers. The flight lines for the 1974 photographic and thermal scanning missions are essentially the same as shown in Figures 3 and 4.

The RB-57 aircraft was equipped with two 9-inch format RC-8 cameras, each with a 6-inch lens, a 9-inch format Zeiss aerial camera with a 12-inch lens, a 70-mm Hasselblad camera with a 40-mm lens, and a RS-7 thermal scanner filtered for the 10.2 to 12.5-m spectral region. Imagery from the various cameras consists of 9-inch Ektachrome Type SO-397, 9-inch and 70-mm Aerochrome infrared Type 2443, and a black and white positive of the RS-7 thermal scanner image. Sequential photography was obtained with the two RC-8 cameras timed for 60% overlap, and the Zeiss camera timed for 22% overlap. As the RB-57 flew at altitudes of 59,000 to 59,800 feet above ground level the exact scale of the photography was 1:118,000 for the 6-inch lens and 1:59,000 for the 12-inch lens. Table 2 shows the imagery acquisition project for the duration of the project.

The quality of the photography varied from good to excellent in the 9-inch format, and from poor to excellent in the 70-mm format. Evaluation of each type of imagery obtained for this study should be helpful for planning future missions.

The Aerochrome Infrared Film (9-inch format) was exposed in two cameras. A 6-inch lens and a 12-inch lens provided scales of 1:120,000 and 1:60,000 respectively. The 1:120.000 scale color infrared photography was used for direct comparison with the Ektachrome Type SO-397, which

TABLE 2. IMAGERY ACQUISITION SCHEDULE

IMAGERY ACQUISITION BY NASA

DATE	AIRCRAFT	MISSION	ALTITUDE	SENSOR	FILM TYPE/ WAVELENGTH
4 June 72	RB 57	205	60,000 ft	RC8, 6" lens	2443
				RC8, 6" lens	S0397
				Zeiss 12" lens	2443
				Hasselblad, 40 mm	2443
				RS-7 - Thermal	10-12 micron
24 June 73	NP-3	235	3,500-4,000	RS-14 Thermal scanner	8-14 micron
				PMIS	K-band
				PRT 5	
3-7 May 74	RB57	273	60,000	RC8, 6" lens	2443
				RC8, 6" lens	S0397
				Zeiss, 12" lens	2443
				Hasselblad, 40 mm and 80 mm lenses	2443
				Hasselblad -3 camera multispectral 40 and 80 mm lenses	2402
31 May 74	NP-3	272	2,500-4,000	PMIS	K-band
				RS-14	8-14 micron
12 June 74	RB57	284	60,000	same as Mission 273.	

IMAGERY ACQUISITION BY INVESTIGATORS

DATE	AIRCRAFT	MISSION	ALTITUDE	SENSOR	FILM TYPE/ WAVELENGTH
3 Oct 73	Cessna		5,000	Hasselblad, 100 mm lens 3 camera multispectral	PX, 2402 2443 EKMS, 2448
7 May 74	Cessna		5,000	Zeiss, 6" lens	2443 PX, 2402

was exposed at the same scale. The 1:60,000 photography used to verify information derived from the smaller scale photography.

1. Aerochrome Infrared Film, Type 2443, 9-inch format, 6-inch lens, scale 1:120,000. The exposure on the film is good to excellent. A slight density difference is noted along one edge of the film. Color saturation is good and the color rendition appears normal for this film. Subject contrast is high but detail in some highlights is washed out.

Land use patterns are readily distinguished but individual units are not easily discerned. Water bodies such as lakes, ponds, rivers and streams are easily seen. Patterns are observed in larger water bodies which may be indicators of waterborne pollutants. A wide disparity is noted in the color rendition of water bodies, and it is obvious that factors other than pollution are contributing to tonal appearance. Some of these factors are depth of water, surface roughness, sun angle and water coloration.

The 1:120,000 scale photography is useful in preparing land use maps of a general nature and is excellent for long-term monitoring of urban expansion. However, the detail available at this scale is not adequate to make positive identification of all observed features. The photography obtained in the 9-inch format with the longer focal length lens (12-inch) was used wherever greater detail was needed in the study.

2. Aerochrome Infrared Film, Type 2443, 9-inch format, 12-inch lens, scale 1:60,000. The exposure on this film is good to excellent. A slight density difference is noted along one edge of the film. Color saturation is good and the color rendition is normal for this film type.

Subject contrast is high and occasional loss of detail is noted in lighter areas.

The detail observed in this photography is excellent. Center markings on highways may be seen, and individual automobiles are seen on highways and in parking lots. Vegetation is readily separated as to type and size. A peculiarity of the imagery is the three-dimensional appearance of the red vegetation. This appearance is very helpful in determining relative vegetation heights. Surface water is contrasted sharply with the background and drainageways are traced with relative ease. Patterns appearing in ground features lead to the speculation that relative surface moisture differences in soils may be seen. Water depth is difficult to estimate but is indicated by changes in the blue rendition of the water. An example seen on the imagery is a large swimming pool, in which the water is a very light blue at one end gradually becoming dark blue at the opposite end. This color gradation is affected by other factors and is not a reliable indicator in all instances. It was found in this study that the aerial photography did not give enough information to allow direct monitoring of point sources of water pollution. It does, however, provide information on gross pollution in water bodies, primarily in those cases where the pollution is highly visible and contrasts with the normal coloration of the water. The ability to do detailed land use and drainage mapping from this scale photography is a principal asset. Smaller scale photography is also useful in land use mapping, when supplemented with adequate larger scale photography for detail checking.

3. Aerochrome Infrared Film, Type 2443, 70-mm format, 40-mm lens, scale 1:450,000. This photography was considered least useful to the study due to some vignetting of the image and a wide exposure variance, ranging from poor to excellent.

Thermal Imagery (RS-7)

Sources of thermal pollution are essentially point sources, and therefore patterns indicative of thermal pollution are generally recognized as thermal plumes emanating from sources such as industrial areas, thermoelectric generating plants (nuclear and conventional fuels), and sewage treatment plants. The detection of thermal plumes is possible on the small scale thermal imagery, but no quantitative assessment of actual temperature differences is possible, since calibrated temperature data are not available. The evidence of thermal pollution is therefore based entirely on relative tone signatures, for example, on a positive film the rendition of dark tones indicates cool temperatures, while light tones indicate warm temperatures.

The thermal imagery was obtained with the RS-7 infrared scanner, sensitive to the 10.2 to 12.5 micron spectral range, which is the far-infrared region of the spectrum. Most thermal imagery is acquired at night to avoid the effect of reflected radiation and at altitudes under 10,000 feet so the resolution will be sufficient for the detection of thermal point sources. This high altitude, daytime imagery was done on an experimental basis, and with some interesting results. In terms of the objectives of this study, few evidences of thermal pollution

patterns could be seen. The only clearly identifiable man-made plume on the original imagery was the plume of the Point Beach Nuclear Power Plant (located at point 4, Figure 5) where thermal differences could be extending about two miles southward of the plant.

The plumes of several rivers entering Lake Michigan and Green Bay include the Milwaukee, the Fox, and the Menominee Rivers, points 3, 7, and 1, respectively in Figure 5. It is normal for the water of rivers entering Lake Michigan and Green Bay to be warmer than the lake water during the spring and early summer seasons. Differences as high as 20°F were measured by the investigators. Therefore, it is difficult if not impossible to estimate how much of the relative warmth of these river plumes is due to natural causes and how much due to heat added from industrial sources. Low altitude, nighttime, thermal scans would provide much more information for this type of problem.

A noticeable aquatic thermal pattern is illustrated at point 2, Figure 5. This pattern is interpreted to be related to major circulation patterns within Green Bay. The fact that the patterns are confined to the water area suggests that the signal does not result from atmospheric temperature differences. The original RS-7 imagery provided numerous patterns related to lake currents and long shore currents in Lake Michigan. The effect was similar to current turbidity patterns seen of the same areas on ERTS MSS bands four and five at approximately the same scale as the RS-7 imagery.

Thermal patterns on the land surface were complex. The most readily distinguishable patterns were forested areas (for example,

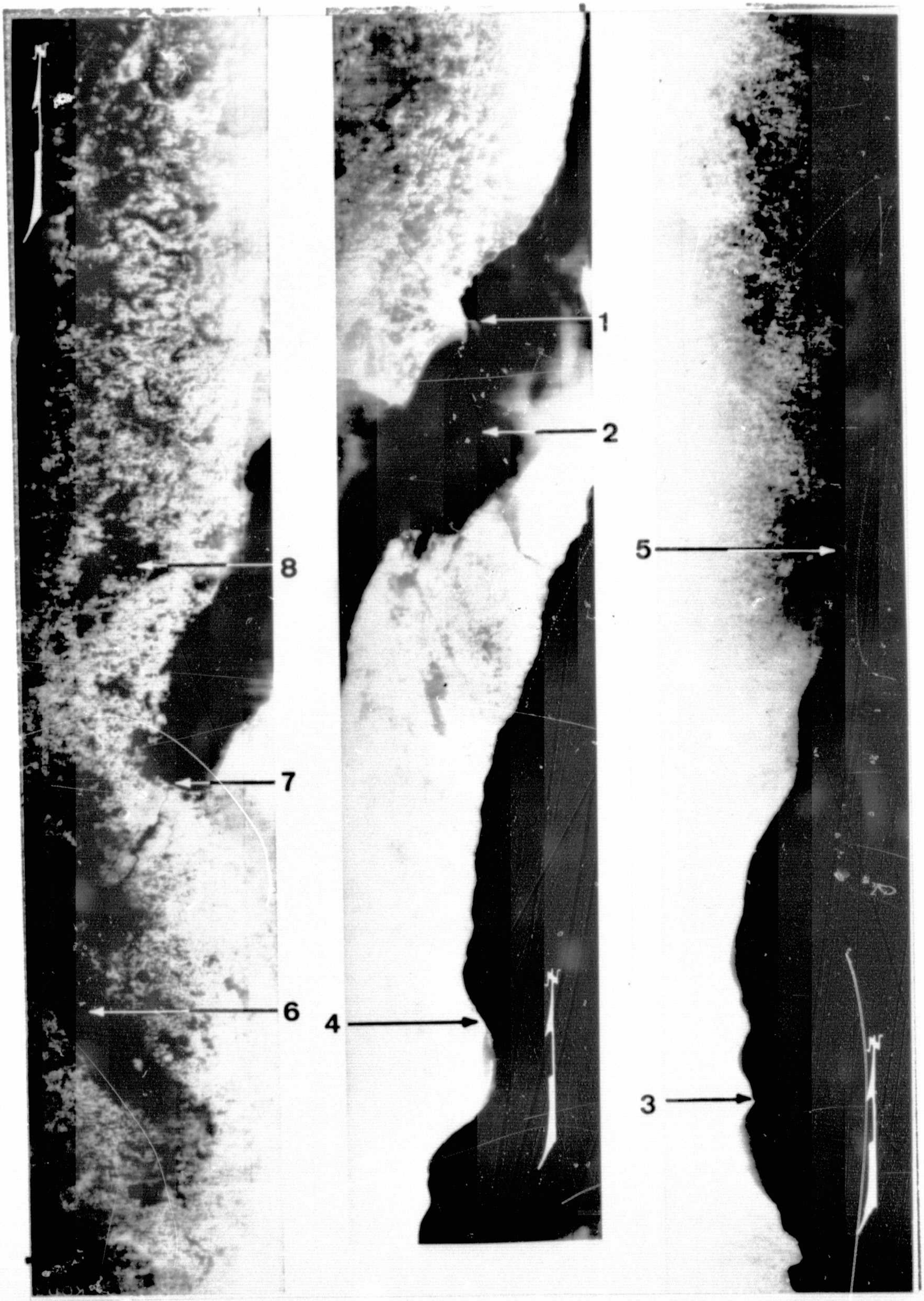


Figure 5. RS-7 high altitude thermal imagery of study area.

point 7, Figure 5) contrasted with cleared agricultural areas and small lakes. Urban areas were not distinct, but always of a light tone on the original imagery, suggesting a "heat island" effect. An example is the city of Sheboygan (point 5, Figure 5). Tonal differences of the urban areas compared to the surrounding countryside suggest ERTS MSS band 7 in appearance.

One of the most noticeable terrestrial patterns on the RS-7 imagery is a dark swath with a northwest to southeast orientation, located between Green Bay and Lake Winnebago (point 6). The probable cause of this cold signal is judged to be precipitation occurring shortly before the time of flight, resulting in higher soil moisture content in this area. The only weather stations located within the dark toned area are Brillion and Kewaunee, which reported 0.68 and 0.69 inches of precipitation, respectively, on 4 June (see Appendix I).

Mission 235, 24 June 73

In June 1973 the NASA NP-3 aircraft flew the RS-14 infrared scanner and the passive microwave imaging system (PMIS) over the test area. Little infrared imagery of usable quality was obtained due to ground fog over the study area. The usable imagery obtained was not in the prime study areas and evaluation was not completed.

The PMIS (Passive Microwave Imaging System) is a recently developed sensor which has not been tested for many potential remote sensing applications. A variety of microwave sensors has been used to measure

parameters of water or ice surfaces, and several federal agencies have sponsored successful research on determination of sea state, water surface temperature, water salinity, oil pollution of water surfaces, and sea mapping.

PMIS System Characteristics

Passive microwave systems do not provide their own energy source. These sensors respond to the energy emitted, reflected and transmitted from surfaces scanned by the sensor. The sum of these three types of energy constitutes the "brightness temperature" of an object. Emitted and reflected energy have an inverse relationship, with their sum being equal to one or "unity". This relationship means that objects which are good reflectors of energy, such as metal roofs and areas of concrete, are generally poor emitters of energy - and vice versa.

The greater variance of reflectivity in any given area, as opposed to variance in emissivity, causes reflected energy to make up the major portion of a microwave signal recorded during daylight hours. Night-time imagery records mostly emitted signals. This variance in reflection and emission causes the differences perceivable on the imagery. According to the Earth Observations Aircraft Remote Sensing Handbook prepared by NASA (Houston), the airborne PMIS gathers brightness temperature data (10.69 GHz: in degrees Kelvin) from two scanning antennae, one for vertical polarization and one for horizontal polarization. Black and white images on a video monitor and digital magnetic tapes are generated aboard the aircraft.

The imagery supplied for evaluation was a computer-processed false color rendition of the scene scanned by the PMIS; each color represented a temperature range of about 4 degrees Kelvin. A total of 64 colors was used. A computer printout of the area represented by the color transparency was supplied with the temperature for each footprint (color segment) given.

The PMIS imagery was acquired on a single flight line of the NASA NP-3 aircraft at an average altitude above the terrain of 4300 feet. The flight line was centered on the Fox River which drains Lake Winnebago and discharges into Green Bay, about 40 miles to the northeast. The land-use patterns along the Fox River covered by the PMIS swath include most of the land-use categories to be found in the eastern Wisconsin test area and form a good basis to examine the applicability of PMIS imagery to land-use patterns in the Great Lakes region. Recent studies conducted at the University of California, Santa Barbara, have suggested that passive microwave imagery could be useful for general land use mapping.

The PMIS system has severe limitations as a remote sensing tool for land-use mapping, however. These include low resolution and small-area coverage. The scanning geometry of the PMIS system is shown in Figure 6 and the formula for determining the size of the PMIS footprint is shown in Figure 7. Applying the formula to the imagery evaluated in this report, the following dimensions are obtained: Footprint length, 464 feet; footprint width, 185 feet; aircraft NADIR to footprint, 5035

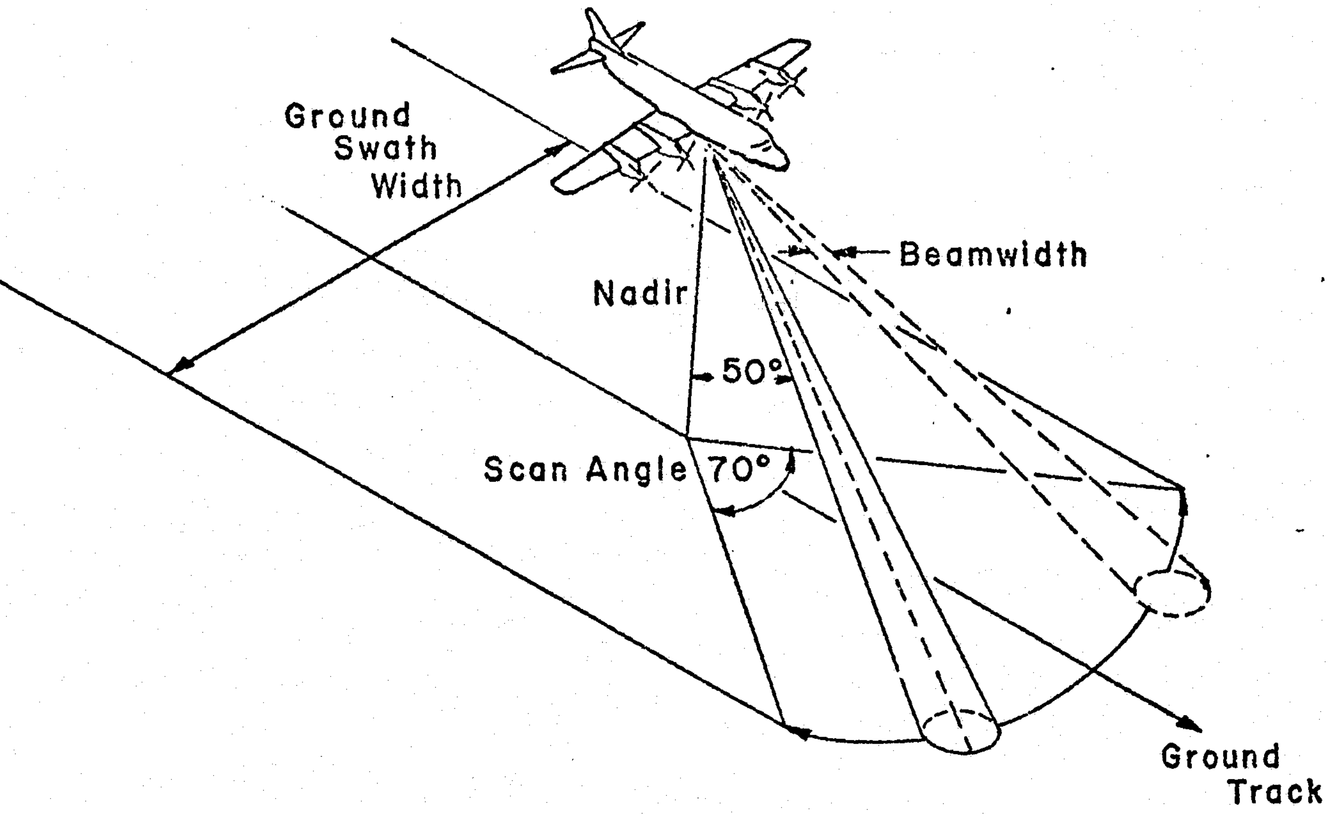
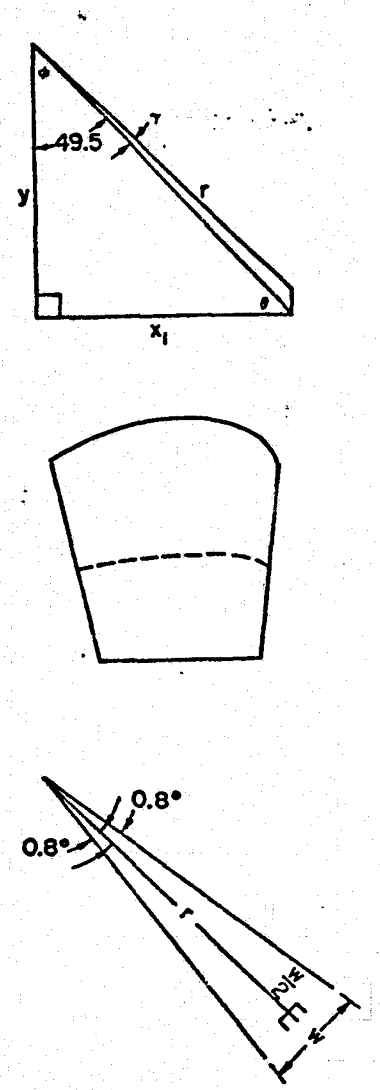


Figure 6. PMIS scanning geometry (Diagrammatic).



center $w^{o} = 1.6^{o}$, $\ell^{o} = 2.6^{o}$
SCAN

Along Axis

$\phi_1 = 48.2^{o}$

$\phi_2 = 50.8^{o}$

$x_2 = 1.226y$

$x_1 = 1.118y$ (dist. from corner to begin of footprint)

$x_2 = x_1$ plus footprint

$\Delta x = .108y$ $(x_2 - x_1)$ length of footprint

$xG = 1.1708y$ (Distance from NADIR to begin. of footprint)

Perp. to Axis

$\cos 49.5 \frac{\psi}{r}$

$r = 647.1$

$\tan 0.8 = \frac{w}{\partial y} (.6494)$

$$w = \frac{2y \tan 0.8^{o}}{0.6494} = .0430y$$

Altitude

$w = rw = \frac{y}{6.594} \left(\frac{1.6\ (2\psi)}{360}\right) = .0430y$ (width of footprint)

Figure 7. PMIS scanning geometry, and formulae for "footprint" determination.

feet. It is interesting to note that from an altitude of 4300 feet, the PMIS footprint size is slightly narrower but considerably longer than the 264 foot circle which comprises a single unit (Pixel) for the ERTS multispectral scanner from an altitude of 496 miles. The PMIS imagery evaluated has a resolution somewhat less than that of the satellite MSS sensor.

Several interpretation approaches were used in the evaluation of the PMIS imagery. The initial approach was to match visually the major patterns of the PMIS imagery with those as seen on Aerochrome IR transparencies and with black and white prints of the study area. A Bausch and Lomb Zoom Transfer Scope (ZTS) was used to match the scales of the imagery for visual comparison and interpretation. It was anticipated that major patterns identified on the photography as forest or agricultural land, residential and industrial areas would correlate with the microwave imagery.

It was not possible to identify the major patterns on the PMIS imagery. The only dependable pattern agreement was the land-water boundaries representing the Fox River and the shore of Green Bay. In some cases other kinds of differentiation could be observed, for instance, the boundary between the central business district in the city of Green Bay and established residential areas where there were many trees. Wet areas and small ponds produced a distinctive signature on the PMIS imagery and could be compared to the photo record for shape and size. The major problem was that such relationships were

not consistent from place to place and pattern interpretation based on the PMIS imagery without conventional photography as ground truth was not feasible.

An attempt was made to correlate the computer printout to the color transparency. A direct correlation could not be made and in many cases a unique footprint shown in the color transparency could not be located on the digital printout for the corresponding scan line. It was possible in most cases to correlate the particular cultural or natural feature as shown on the color infrared with outstanding footprints on the PMIS imagery. A summary of interpreted relationships is shown in Table 3. Possible causes of this lack of correlation are, (1) individual scan lines are not properly synchronized with the computer printout, (2) the imagery may show unique segments when the brightness temperatures do not change significantly, or (3) the time index printed on the imagery or the time indication on the computer printout may be incorrect. The best method of evaluation was a simple visual comparison of the PMIS imagery to conventional photography.

The particular PMIS computer imagery evaluated in this project did not provide satisfactory results for the purposes of investigating land use. Wetlands were visible on the imagery, but the possibility of confusing such terrain with various other phenomena that produce similar tonal of signatures is too great to be overlooked. One cluster of buildings may appear as a white or pink area on the imagery, while a similar group of adjacent buildings is not represented at all. Of two

TABLE 3. TYPICAL PMIS SIGNATURES

Temp Range °K	Polarization	Interpreted Phenomena
50-82	Vertical	-
	Horizontal	-
83-122	Vertical	-
	Horizontal	Water, Agricultural Land
123-226	Vertical	Water, Wet Lands, Industrial Areas (Metal Roofs)
	Horizontal	Water, wetlands, Residential Areas, Industrial Areas (Metal Roofs)
227-258	Vertical	"Boat Berths", Residential Areas, Industrial Areas (Metal Roofs), Agricultural Areas, Heavily Vegetated Areas, Isolated Metal-Roofed Buildings, Trailer Park, Bare Soil Areas
	Horizontal	Residential Areas, Industrial Areas (Metal Roofs), Agricultural Areas, Heavily Vegetated Areas
259-300	Vertical	Industrial Areas, Residential Areas
	Horizontal	Residential Areas

adjacent ponds of similar size, one may be visible and the other not shown. On the basis of color or tone signature, heavily vegetated areas cannot be separated from residential or industrial areas. In some cases, land could not be distinguished from water on the microwave imagery. Some roofs showing white on the imagery could be mistaken for ponds, as they also may be white on the imagery. This type of identification problem dominated correlative attempts based upon color and tone on the PMIS imagery.

It is hoped that further experimentation with PMIS will provide more satisfactory results. The ability of the PMIS to obtain surface information through cloud cover is a an asset and could prove a valuable tool in remote sensing of water and wetland resources.

With regard to possible practical applications of the PMIS as a remote sensing tool in the Eastern Wisconsin test area, it would appear there are severe limitations, especially for terrestrial applications. These include low resolution coupled with small area coverage, in addition to the difficulties of scan line identification and numerical correlation of the colors represented on the imagery. This evaluation did not include most of the traditional applications of passive microwave sensors which are primarily related to water surfaces. Also the use of PMIS for the differentiation of soil moisture was not sufficiently tested due to the uniformity of soil type within the Fox River valley. The few areas of wetlands or fill were for the most part detectable. A comparison of PMIS imagery with RC-8 photographic imagery is shown in Figure 8. The scale of the PMIS imagery in Figure 8 is slightly smaller

Figure 8. Comparison of PMIS imager with high altitude color infrared imagery.

in its long axis compared to the RC-8 photographic image so that comparable points do not register exactly left and right. Although both originals were in color, this black and white reproduction provides considerable information on signature comparability. The major water bodies, Green Bay and the Fox River, are easily defined in both types of imagery. These areas have been filled with dredge spoils, but are mostly low and wet. The residential areas (pt 4, Figure 8) appear as a warm signal in the PMIS, probably due to dense tree growth. The central business district of Green Bay, (pt 2) gives a mixed signal. The arc of cold (light toned) signals just below this point is an error, due to a tilt of the sensing aircraft at this point. (Paper mills, pts. 3, Figure 8) provide a cold PMIS signal, and are highly reflective in the photographic wavelengths.

For land-use mapping and other terrestrial applications in the eastern Wisconsin test area, the PMIS does not appear to be a practical tool. The only clear advantage it has over other available sensors is that imagery can be acquired under adverse weather conditions. Although more detailed processing at the PMIS ground data station and imagery acquired at a lower altitude would provide more detail, it appears unlikely that this sensor could provide data for land-use mapping comparable for most practical applications to either thermal scanning or photographic sensors.

Missions 273 and 284, May-June 1974

Ektachrome type SO-397 2A Filter (Mission 273) scale 1:114,000:

The 9-inch format Ektachrome type SO-397 was exposed in a RC-8 metric camera equipped with a 6-inch lens and a 2A filter. The film is slightly underexposed or dark and the color balance appears normal. Some detail is lacking in water bodies due to the exposure. Overall detail is good and land-use patterns are easily observed. Contrast varies from good in the center of the frame to low around the frame edges.

Aerochrome IR film, type 2443 12 Filter (mission 273), 9-inch format, 6-inch lens, scale 1:114,000:

The film is considerably overexposed (light) and vignetted. Frame corners are dark and the center is light. Subject contrast is high with some detail washed out in highlight areas. Film color balance appears shifted to green.

Aerochrome IR film 12 Filter, type 2443 (mission 273), 9-inch format, 12-inch lens scale 1:57,000:

The exposure, color balance and detail of this film are excellent. A slight density difference occurs between the center of the film and the edges as well as a slight color shift associated with the density change. Several large marks (scratches or abrasions), are noted on many frames of the film but these did not cause problems in interpretation of land use features. They do, however, show up on enlargements of the imagery and detract from its overall appearance. This film

and scale of photography provides all of the information needed for gross land use mapping and, as was discussed earlier, was used wherever greater detail was needed to verify mapping from the smaller scale photography.

Aerochrome Infrared, type 2443, 70 mm format (2 1/4" square) 12 + 30B filter:

The photography flown on 3 May 1974 was exposed with 40 mm lenses on the Hasselblad cameras while the photography flown on 7 May 1974 was exposed with 80 mm lenses. The usefulness of the two days' photography varied considerably. Large patterns such as urban areas, large lakes or ponds and streams can be seen but finer detail needed for land-use mapping is missing. The probable cause for such poor resolution is atmospheric attenuation coupled with exposure variances. The 70 mm format is more difficult to work with when doing mapping and is considered the least desirable for land-use mapping.

Mission 272, 31 May 74

This mission was a repeat of Mission 235, a low altitude thermal and microwave scanning flight by the NASA NP-3 aircraft. Only the PMIS imagery from Mission 235 was analyzed with any detail because ground fog obscured much of the RS-14 thermal imagery. Mission 272 was flown on 31 May 74, approximately 2100 to 2400 hours local time. Flight lines indicated in Figure 3, are applicable to both Mission 235 and 272. Aircraft coverage of the Fox River was at 2500 feet (radiometric altitude). The rest of the coverage, including the Lake Michigan shoreline and the Manitowoc, Sheboygan and Milwaukee Rivers was at approximately 3500

feet (radiometric altitude). This evaluation focuses primarily on the RS-14 imagery of the Manitowoc River and briefly on the larger scale coverage of the Fox River. PMIS data acquired during this mission was not received by the investigators nor was data resulting from the PRT-5 radiometric thermometer intended for correlation with the RS-14 imagery.

The RS-14 thermal scan provided imagery in the 8 to 14 micron wavelengths. The imagery was acquired at night so that only emitted thermal radiation would be recorded. The clarity of the thermal imagery acquired during Mission 272 is excellent. Except for the presence of scan lines, much of the imagery approaches photographic quality in terms of information content available for interpretation.

The primary consideration in this evaluation of RS-14 thermal imagery is its application to the Corps of Engineers mission work. The acquisition of thermal imagery is considerably more expensive than that of photographic imagery. This discussion compares the information content of the thermal imagery with color infrared photographic imagery acquired during Mission 273.

Details of the RS-14 thermal scan of the Manitowoc River were compared with a 1:60,000 scale color infrared photograph acquired 23 days prior to the thermal scan. Figure 9 is a negative rendition of this RS-14 imagery. Very little water detail is visible in either type of imagery except at the wider portions near the river mouth. On the RS-14 imagery, temperature differences attributed to the mixing of cooler lake water with that of the river can be detected as a gradual

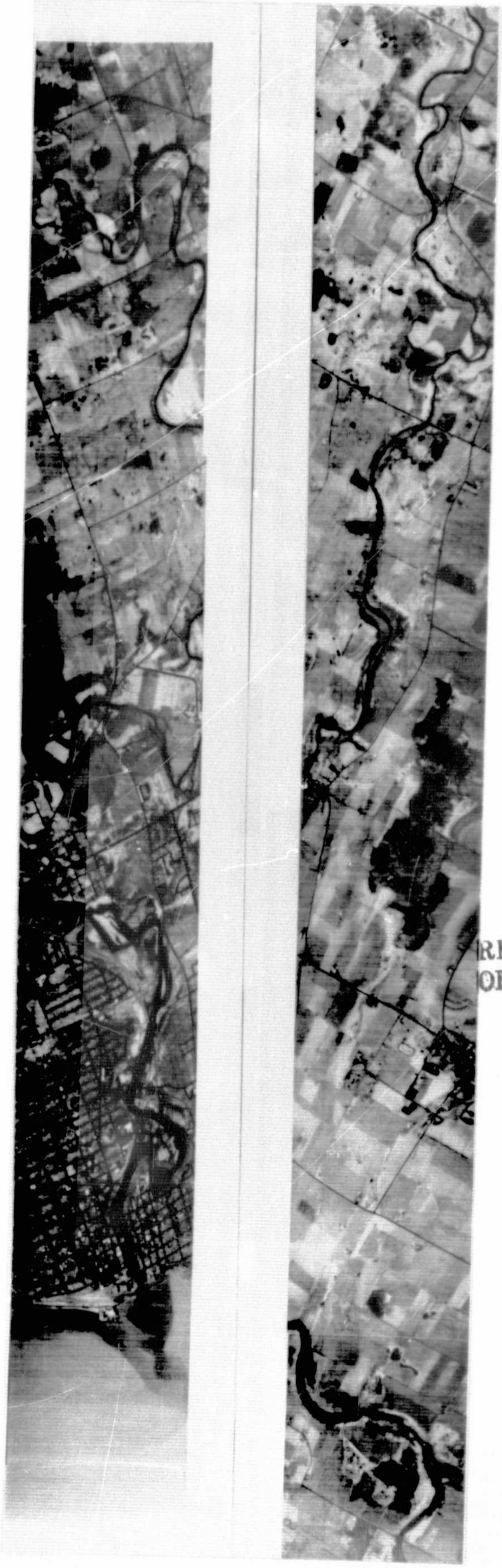


Figure 9. RS-14 imagery of the Manitowoc River (negative rendition).

shading from the harbor area to approximately one mile upstream. This differentiation is not observable in the color infrared imagery. An indication of a warm signature resulting from sewage plant effluent is visible near the harbor entrance on the RS-14 imagery but not on the Zeiss imagery. This small plume was readily detectable, however, on color infrared imagery acquired by the investigators at an aircraft altitude of 5,000 feet two months prior to this flight.

Details of drainage, apparent soil moisture differences and forested areas are as evident as those on the color infrared photograph used for comparison. Agricultural land use patterns, such as differentiation of field boundaries, roads and other cultural patterns, are readily apparent on the RS-14 imagery. Apparent differences in surface materials on roads were noted on the RS-14 imagery but not on the color infrared. The RS-14 imagery of the urbanized area of Manitowoc displayed considerable detail, particularly street patterns and large building structures.

A section of the Fox River between Neenah and Menasha is shown to illustrate the clarity of wetlands delineation on the RS-14 imagery (Fig. 10). A black and white reproduction of an RC-8 color infrared imag of the region to provide a geographic reference. The warm shallow water within the wetlands and in a small stream entering the wetland area provide detail generally not available on photographic imagery.

The analysis of the RS-14 thermal imagery as compared to color infrared photographic imagery indicates that many of the patterns displayed on the thermal imagery are readily detectable on photographic

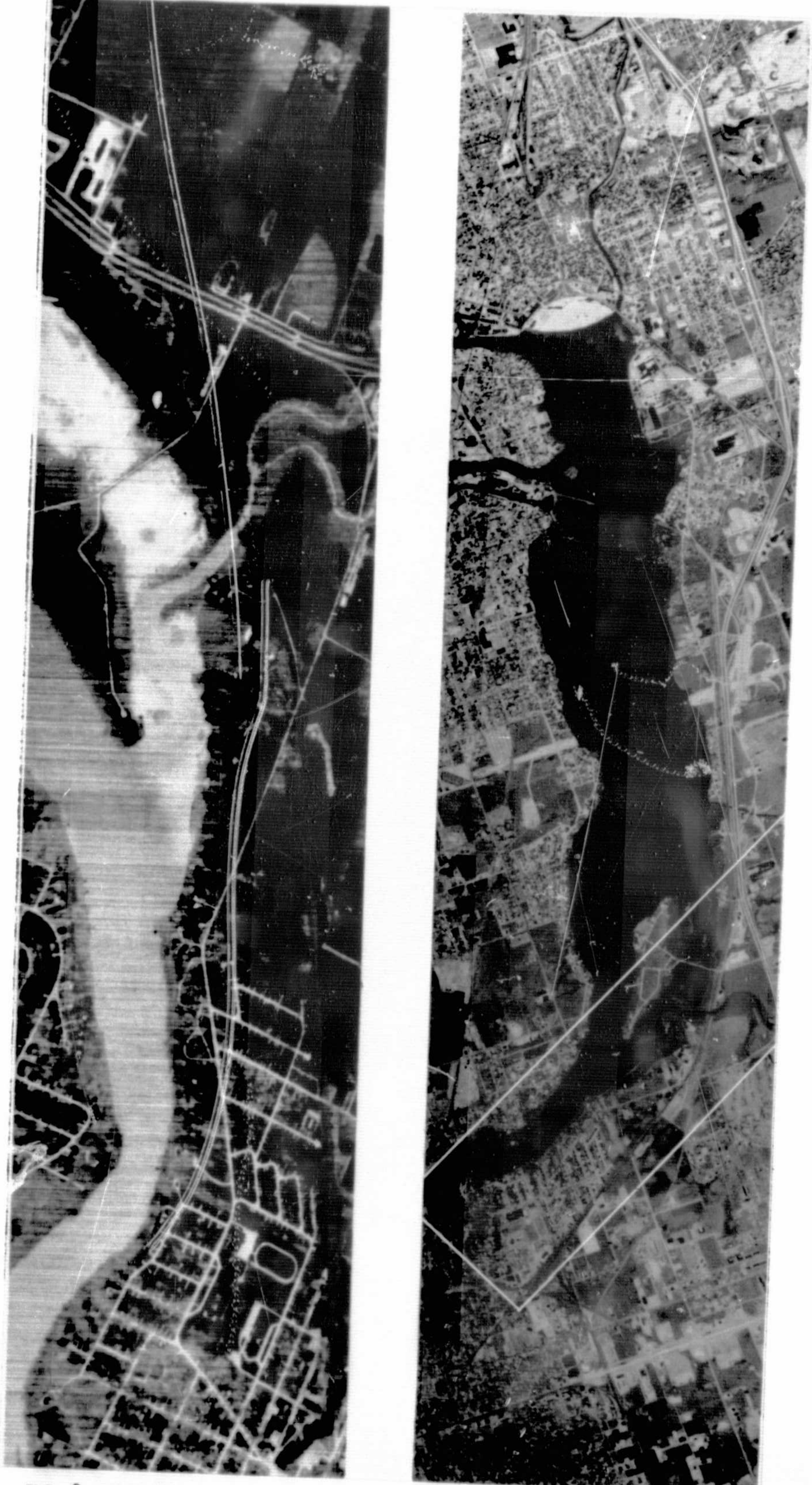


Figure 10. RC-8 and RS-14 imagery of the Fox River between Neenah and Menasha.

imagery, especially color infrared emulsions. In cases where relative temperature information is desired for a land or water surface, there is no substitute for the thermal scanner. However, for most purposes, sufficient information can be obtained much more economically with aerial photography. For instance, the identification of effluents in water bodies can be done whenever the effluent enters a water body with a different turbidity or color. There were few cases where effluent plumes identifiable on the RS-14 imagery did not create an identifiable signature on either high altitude color or color infrared imagery. In the study area, color infrared and/or color imagery acquired at a similar scale to the thermal imagery can be used to locate most types of effluents. However, details of the plumes such as the size and concentration within mixing zones, would be far better depicted by thermal imagery. Although much detail on land use patterns is portrayed in the thermal imagery, its application in a mapping program should be limited to a few specialized areas. For general mapping efforts the low resolution, narrow field of coverage, lack of geometric control and high expense preclude the use of thermal imagers. For specialized applications the thermal scanner may be the only feasible sensor, for example, the delineation of impervious areas within a city, or differentiation of small drainage patterns within a wetlands area.

<u>70 mm Hasselblad multi-spectral photography, 2 1/4" sq. black and white, 25, 47 filters, 2402, 2442 film</u>

The Hasselblad system was used to obtain black and white photography of the test areas which would approximate the various spectral bands

used in the ERTS-1 (blue, green, red and near IR). The quality of the photography is poor in most instances. The film is grainy; some rolls show extensive water spotting; resolution is poor and contrast is flat. The 2402 film with 25 filter produced the best result for single band viewing and was the only band considered suitable for gross land-use mapping (level 1); color reconstruction of selected scenes was attempted using the multi-spectral viewer. The usefulness of this technique (optical mixing) was limited due to the quality of the photography. It is possible to emphasize natural and cultural features using the multi-spectral viewer but in no instance was more information obtained from this technique than could be obtained from the larger color transparencies.

<u>Mission 284, 12 June 1974</u>

Mission 284 was flown on 12 June 1974 and additional photography of lines 22 and 23 obtained. The cameras used were two Wild RC-8 metric cameras (9-inch format, 6-inch lens), the Zeiss metric camera (9-inch format, 12-inch lens), and 4 Hasselblad cameras with 80 mm lenses. The Hasselblad cameras exposed plus-X Aerographic film, type 2402 through a 12, 57 and 47 filter and Aerochrome IR, type 2443, through a 12 + CC 30B filter. Nine-inch Aerochrome IR, type 2443, was exposed in one of the RC-8 cameras and in the Zeiss camera with a 15A filter. The other RC-8 camera exposed Ektachrome (SO-397) through a 2A filter. This photography is excellent and is technically some of the best received from NASA.

LAND USE ANALYSIS

The initial step in the land use analysis portion of this study was to determine land use mapping criteria which would permit a quantitative comparison to water quality measurements. Most urban and many agricultural point sources can be directly related to a potential for aquatic or other types of pollution but meaningful areal measurements cannot be obtained (Fig. 4). Although changes in number and types of point sources will occur as land use patterns evolve, the size of the site or land area occupied by a typical point source is not directly related to the intensity or type of pollution. The development of a data base for land use/water quality comparisons was, therefore, restricted to levels I, II, and III land use categories that lend themselves to area measurements rather than enumeration of point sources. The investigation was then focused on the regional relationship of land use categories to sediment loading in streams.

The USGS Land Use Classification System (Anderson, et. al., 1972) was selected for use in this investigation. "The classification system utilizes the best features of existing widely used classification systems to the extent that they are amenable to use with remote-sensing, and it is open-ended so that regional, state, and local agencies may develop more detailed land use classification systems, at third and fourth levels, to meet their particular needs and at the same time remain compatible with each other and with the national system." (Anderson, et. al., 1972). An outline of the system is shown in Table 4. This

TABLE 4. LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Level I	Level II
01. Urban and Built-up Land	01. Residential
	02. Commercial and services
	03. Industrial
	04. Extractive
	05. Transportation, Communications, and Utilities
	06. Institutional
	07. Strip and Clustered Settlement
	08. Mixed
	09. Open and Other
02. Agricultural Land	01. Cropland and Pasture
	02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas
	03. Feeding Operations
	04. Other
03. Rangeland	01. Grass
	02. Savannas (Palmetto Prairies)
	03. Chaparral
	04. Desert Shrub
04. Forest Land	01. Deciduous
	02. Evergreen (Coniferous and Other)
	03. Mixed
05. Water	01. Streams and Waterways
	02. Lakes
	03. Reservoirs
	04. Bays and Estuaries
	05. Other
06. Nonforested Wetland	01. Vegetated
	02. Bare
07. Barren Land	01. Salt Flats
	02. Beaches
	03. Sand Other Than Beaches
	04. Bare Exposed Rock
	05. Other
08. Tundra	01. Tundra
09. Permanent Snow and Icefields	01. Permanent Snow and Icefields

system is adaptable to three levels of organization. Levels I and II are readily mapped from most types of aircraft photography and require a minimum of ground truth data for verification. The only extensive ground truth needed would be that required for some level III land use mapping. Level II mapping was accomplished on a small area primarily to compare content and efficiency of mapping from ERTS-1 vs. high altitude aircraft imagery (Haugen and Splett, 1974). The only level III categories utilized were to differentiate between open agricultural land and that with a cover crop.

A variety of high altitude imagery was obtained by NASA in May and June of 1972 and 1974 for this project. For land use mapping, the color infrared imagery acquired from the RC-8 (6" lens) and especially the Zeiss (12" lens) cameras was most suitable. Approximate scales were 1:120,000 and 1:60,000 respectively. The RC-8 color infrared transparencies were contact printed to obtain black and white negatives and were enlarged to a print scale of 1:63360 for use with acetate watershed outline maps prepared from USGS 15 minute topographic maps. Although the Zeiss 1:60,000 provided the greatest detail, mission restrictions precluded complete area coverage with this camera. Interpretation was done directly on the acetate overlays. The 9"x9" color transparencies were placed on a nearby light box for constant reference during this procedure.

Analysis of 1972 Imagery

The East and West Twin River watersheds were selected for the initial mapping effort because the photography showed obvious color-density differences between the two streams, which suggested apparent

variations in sediment load. The object was to correlate the apparent changes in sediment load to land use. Since the 1:120,000 color infrared imagery provided the greatest amount of information on land use differences, it was used for land use interpretation. Basic details such as roads, streams and watershed boundaries were transferred directly from the base map to an acetate overlay with predrawn linear features to provide control for distortions on the black and white photo enlargements.

Land use for the Twin Rivers watersheds was mapped using the basic procedures already described. Colors were chosen for the manuscript map based on their optical density to allow measurement of areas through color densitometer planimetry. The photo base map and the manuscript land use map are illustrated in Figures 11 and 12. Unfortunately the colors most suitable to color densitometry do not reproduce well in black and white photography, so the categories are difficult to discern in the illustration.

The instrument used was an Antech model A-12 densitometer, which consists of a black and white TV camera especially modified for uniform sensitivity across its entire scan area, a color TV receiver, and an electronics package including a digital planimeter. The instrument converts density levels into different voltages which are then displayed as discrete colors and/or numerical values. The range of density values examined is adjustable, and the assignment of specific colors to given density values is operator-controlled. A "color window" feature permits the analysis of a variable sized square or rectangular area within the scanned area. The planimeter feature provides a direct

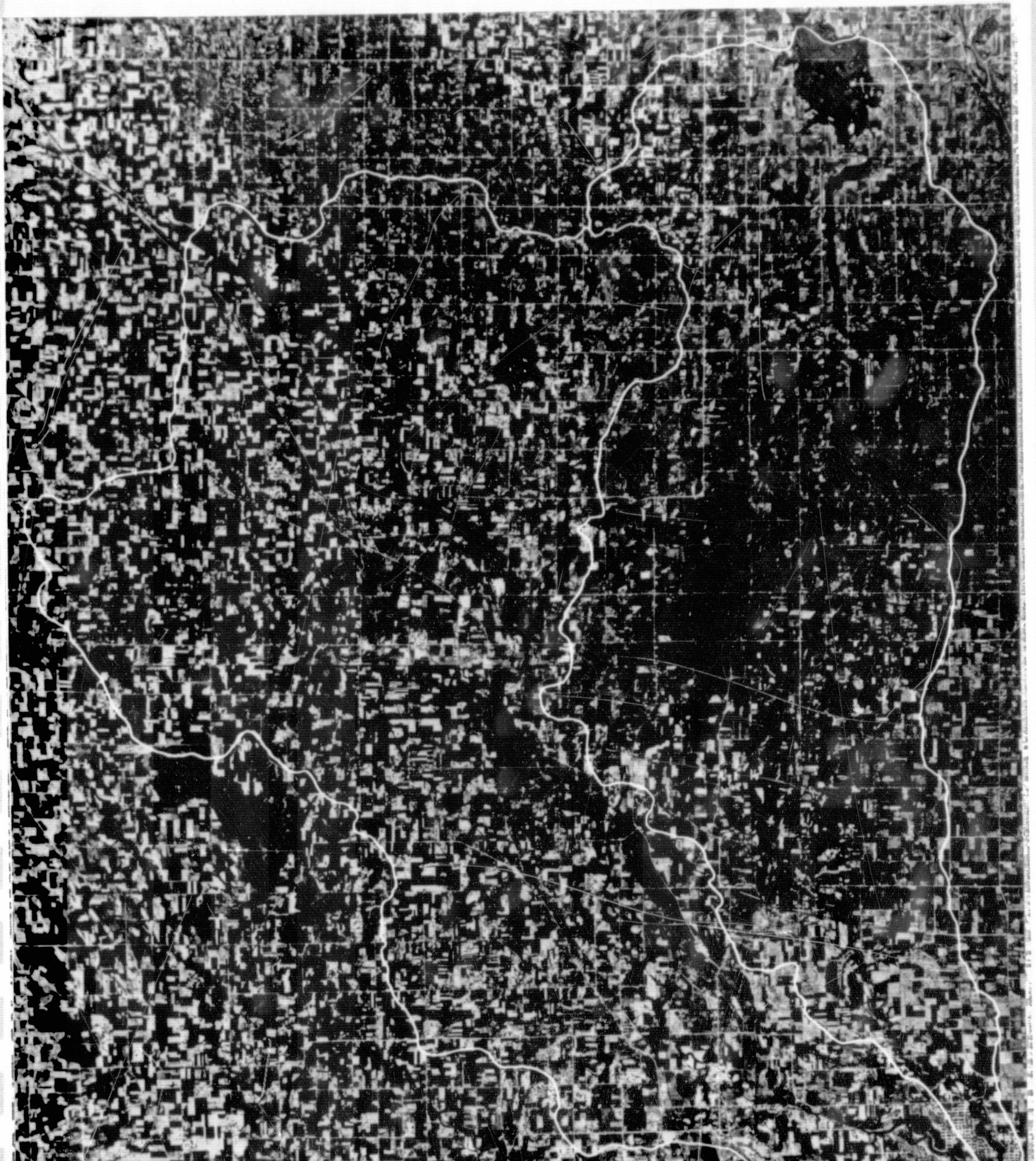


Figure 11. Photo base map with watershed outlines of East and West Twin Rivers.

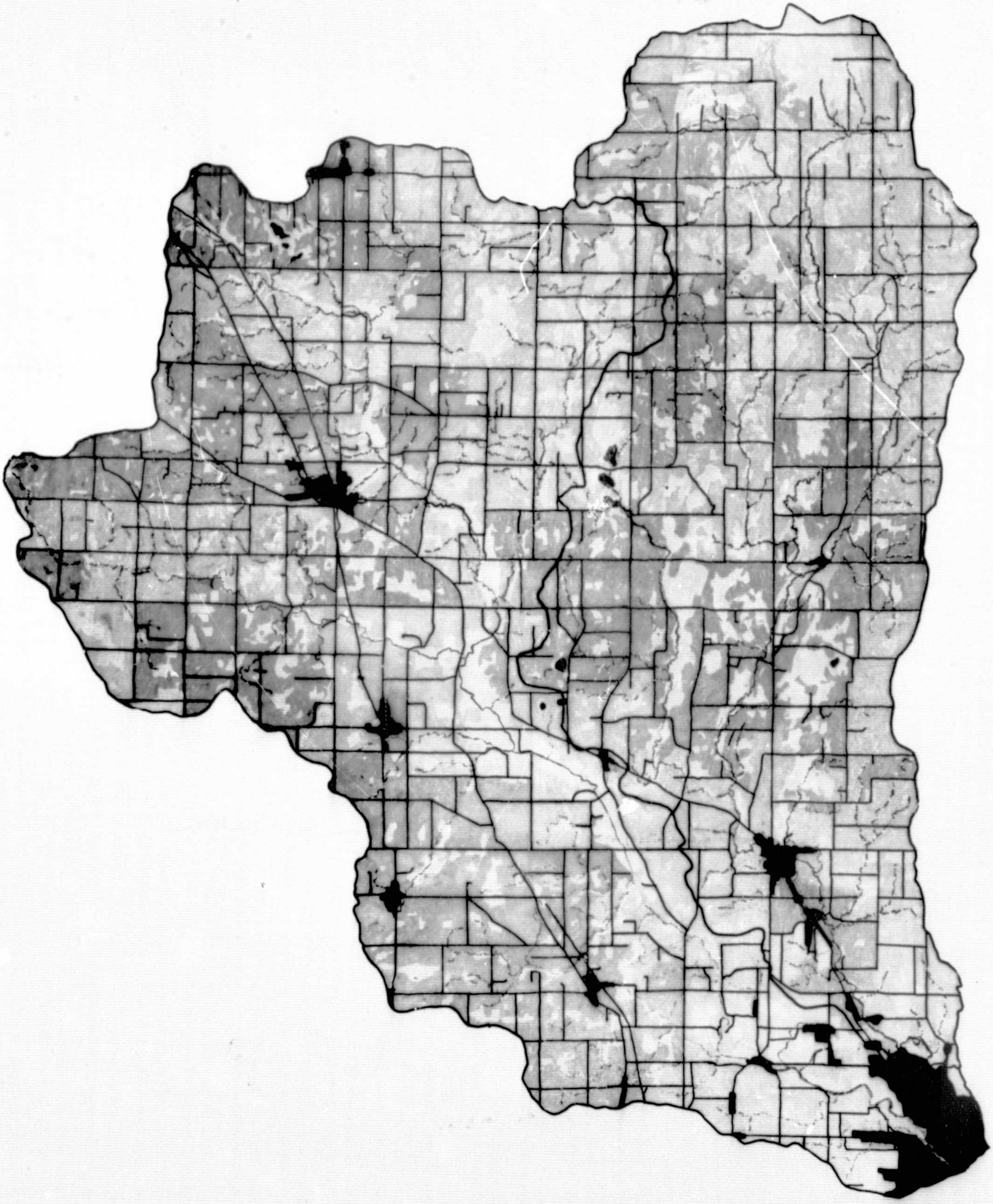


Figure 12. Black and white reproduction of manuscript land use map.

readout of the proportion of the window in a given color or density level. Using the densitometer planimetry method, 97-99% accuracy is achieved, provided the initial mapping is correct.

The color window must be calibrated to correspond to a known area on the acetate or base map. Since the mapping was done at a scale of 1 inch equals 1 mile, a grid network (Fig. 13) representing 16 square inches on the base map, or about 10,240 acres on the ground was established. This block size was selected because it yielded maximum results in terms of accuracy and size measurement. The grid was applied to the Twin Rivers watersheds and the resulting measurements are indicated in Tables 5 and 6.

In the above analysis an experiment was accomplished using the color densitometer to measure land use areas directly from the color and color infrared imagery. Color filters were employed to emphasize tonal patterns and to vary contrast differences indigenous to the imagery. The obvious advantage of this procedure is that manual mapping of land use would be eliminated and data for comparison to stream sedimentation and other water quality measurements could be obtained directly. Also, maps of land use could be compiled by simply photographing the individual sections on the densitometer screen during that procedure.

The direct measurement of land use areas from the photography proved to be feasible for limited areas. Only those areas with light-toned soils provided sufficient color density contrast between open fields and crops and other vegetation. Other land use categories, notably forest and roads, almost always could be distinguished and directly measured.

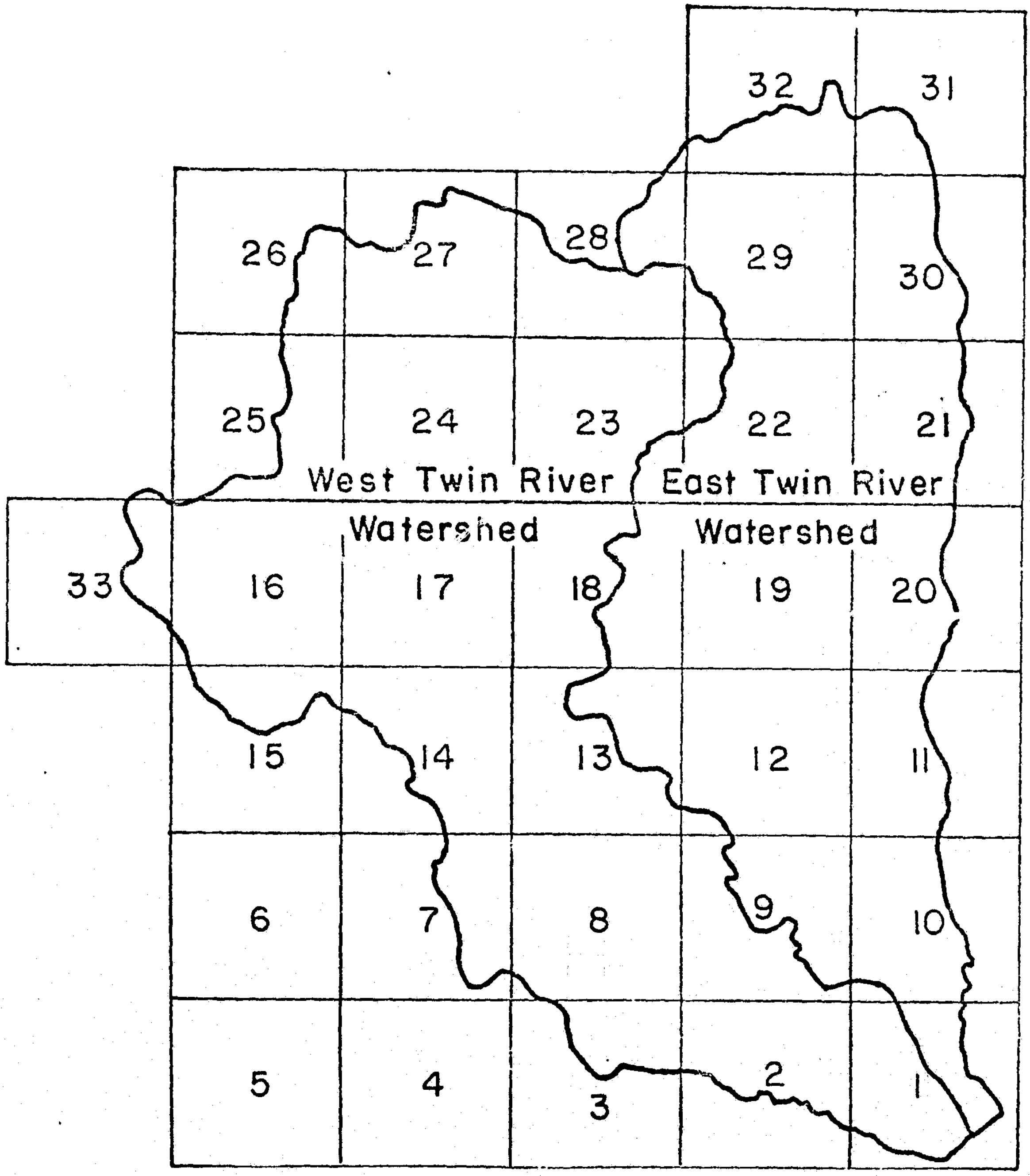


Figure 13. Grid used for densitometer measurement.

TABLE 5. AREA OF LAND USE TYPES, EAST TWIN RIVER WATERSHED

Meas. block	Forest %	Forest Acres	Urban %	Urban Acres	Agriculture %	Agriculture Acres	Other* %	Other* Acres	
1	4.6	471	12.7	1301	8.4	860	0.9	72	
10	15.7	1608	1.8	184	43.1	4413	4.1	420	
9	8.3	850	5.1	522	27.1	2775	1.0	102	
13	4.9	503	0	0	15.4	1577	1.2	123	
12	27.6	2826	0	0	59.5	6093	3.1	317	
11	9.7	993	0	0	29.8	3052	3.5	358	
20	9.0	922	3.5	358	44.4	4547	2.8	287	
19	36.0	3686	0.1	10	55.1	5642	4.7	481	
18	6.9	707	0	0	19.8	2028	2.2	225	
23	2.3	236	0	0	3.5	358	0.1	10	
22	24.0	2458	0	0	55.4	5673	1.1	113	
21	17.4	1782	0	0	51.2	5243	2.7	277	
30	13.1	1341	0	0	39.3	4024	4.3	440	
29	33.1	3389	0	0	52.1	5335	5.3	543	
28	3.4	348	0	0	7.6	778	0.5	51	
32	10.4	1065	0	0	6.2	635	3.0	307	
31	2.6	266	0	0	2.9	297	1.1	113	
Totals	28	3,430	3	2,375	64	53,330	5	5,257	83,414

* This category includes watershed boundary lines, roads, rivers, etc.

TABLE 6. AREA OF LAND USE TYPES, WEST TWIN RIVER WATERSHED

Meas. block	Forest %	Forest Acres	Urban %	Urban Acres	Agriculture %	Agriculture Acres	Other* %	Other* Acres	
1	15.7	1608	16.0	1638	15.2	1556	6.1	625	
2	18.8	1925	4.2	430	39.8	4076	3.5	358	
3	9.0	922	0	0	22.0	2252	0.7	717	
7	6.8	696	2.8	287	23.4	2396	.8	819	
15	8.0	819	0	0	24.3	2488	2.9	297	
14	11.1	1137	5.6	573	60.1	6154	2.2	225	
8	17.1	1751	5.1	522	72.2	7393	5.1	522	
9	6.4	655	0.1	10	34.7	3553	3.3	388	
12	0.6	614	0	0	1.0	102	0.1	10	
13	29.2	2990	0.9	92	39.2	4014	6.1	625	
16	18.2	1864	0	0	77.2	7905	1.8	205	
17	21.2	2171	8.2	840	65.7	6728	3.1	317	
18	14.4	1475	0	0	45.1	4618	1.6	164	
25	6.5	666	0	0	34.7	3553	1.4	143	
24	15.4	1577	0	0	65.8	6738	10.1	1034	
23	24.3	2488	0	0	54.8	5612	5.1	522	
22	0.2	20	0	0	7.7	789	0	0	
28	9.4	963	0	0	18.2	1864	0.9	92	
29	0.4	41	0	0	1.3	133	0	0	
27	8.0	819	3.6	369	36.3	3717	0.7	72	
26	5.7	584	0	0	7.7	789	2.2	225	
	0	0	0	0	0.9	92	0	0	
33	2.1	215	0	0	13.5	1382	0	0	
Totals	22	16,000	4	4,761	67	77,904	6	7,360	116,025

* This category includes watershed boundary lines, roads, rivers, etc.

However, the method was not considered feasible because all of the level I categories could not be measured exactly from place to place within watershed areas.

The next approach to land use mapping involved hand colored overlays on frosted acetate, but with three important differences from the original effort on the Twin Rivers watersheds. First, a subcategory was created to distinguish "open" agricultural land, essentially areas of bare soil where crops had not yet reached sufficient density (maturity) to produce a signature on the color infrared imagery. Such land, being more subject to erosion, would contribute directly to turbidity differences in streams. The turbidity differences were apparent in the imagery and could be measured by the analysis of water samples. Secondly, this mapping effort was done directly on an overlay of the 1:120,000 color infrared imagery. The geometric control originally provided by USGS base maps was not believed critical to the measurement of land use areas. The smaller scale together with the procedure of mapping directly from the color infrared imagery was considerably faster. The third difference was the production of a strip map which furnished a sampling of land use units representative of the watershed area. Two grids - one with two square miles, and one with eight square miles were prepared for equal sampling to include at least one mile on each side of the stream. The small grid square was used where the stream was more or less straight, the larger grid was used where streams bifurcated or major curves were encountered.

Two watersheds were mapped and measured using this procedure, the Oconto (1060 square miles) and the Manitowoc (557 square miles). The Oconto, located in the northern part of the test area, is in a predominantly forested area with few apparent sources of aquatic pollution. The Manitowoc watershed had a proportion of land use categories typical of the Eastern Wisconsin test area. Measurements of land use areas for the Oconto and Manitowoc watersheds using the strip mapping method are given in Appendix 2. This technique resulted in a mapping area approximately one third of the total watershed.

There is a bias in the use of strip mapping for measurement of land use categories within a watershed because land use within two miles of a stream is not necessarily representative of the proportions of land use within the entire watershed. However, it can be argued that for purposes of studying the relationships among land use practices, stream sedimentation and other water quality measurements, the resultant data from this procedure is pertinent.

<u>Analysis of 1974 Imagery</u>

Several changes in the mapping approach were made based on experience gained in the mapping effort described above utilizing the 1972 imagery. Instead of using colors on a single overlay map as in the initial procedure, greater measurement accuracy could be achieved with the densitometer/planimeter by delineating land use with black ink on separate overlays for each category. Although mapping with colors is the more rapid method, boundaries are not as distinct and measurement with the

densitometer is more difficult. This is due to the unavoidable density differences in the colored patterns on acetate and also to the similarity of color densities.

The East Twin River watershed was selected as a test area for this mapping approach. This watershed is small (approximately 131 square miles) compared to the Oconto and Manitowoc watersheds, and water samples had been obtained at several locations along the East Twin River. The 1974 color imagery was used to prepare a black and white photographic base map at a scale of 1:63360. The 1974 color infrared imagery was overexposed and could not be utilized for enlargement.

Five acetate overlay maps were prepared for the East Twin River watershed at a 1:63360 scale representing agriculture (open), agriculture (closed), forest, urban, and water. This total watershed map provided an accurate basis for evaluation of previous and future mapping techniques. A reproduction of these overlays with base photo map can be found in pocket (Appendix III). The time required to map an entire watershed at the 1:63360 scale was too great with regard to the principle objective of obtaining quantitative land use data for several representative watersheds.

Therefore, a second sampling technique was devised and tested for precision against the totally mapped East Twin River watershed. One square mile (one section) was established as the sampling unit. A computer-generated listing of random numbers was obtained to provide a 25% sample for grid matrices of 3X3, 4X4, 6X6, and 12X12 units. The different sizes were necessary to provide a "best fit" when the grids

were systematically overlayed on the irregularly shaped watershed. The grid is illustrated in Figure 14. The grids were applied to a watershed mosaic composed of USGS topographic maps. The random numbers, identified as to row and column for each grid, were used to locate the one square mile sample areas. Frequently roads, conspicuous on the imagery, followed section lines. The exact location of a section-sized area was varied slightly from the location indicated by the grid so as to conform to these boundaries for ease in subsequent mapping. For the East Twin River watershed the 25% sample provided 36 one-mile squares to be mapped.

Measurement was done with the color densitometer as previously described. In this case, two factors contribute to greater measurement accuracy; 1) the color window could be calibrated to conform exactly to the one square mile size, and 2) the black ink patterns created only one density level so the density settings of the instrument remained constant. To verify the sampling method, the entire East Twin River watershed map overlays were measured using larger grid squares and the results compared. These results indicated that the 25% sample was within 8% of the values obtained from the total sample for all categories and within 4% for the majority of categories. The bias experienced with the strip mapping approach was avoided.

For the mapping and measurement of the Oconto and Manitowoc watersheds, the 25% sample approach was used. Overlay maps were produced from the 1:120,000 color infrared imagery. This imagery, although overexposed, contained enough detail to permit direct interpretation. Further time saving resulted from combining the mapped categories on a

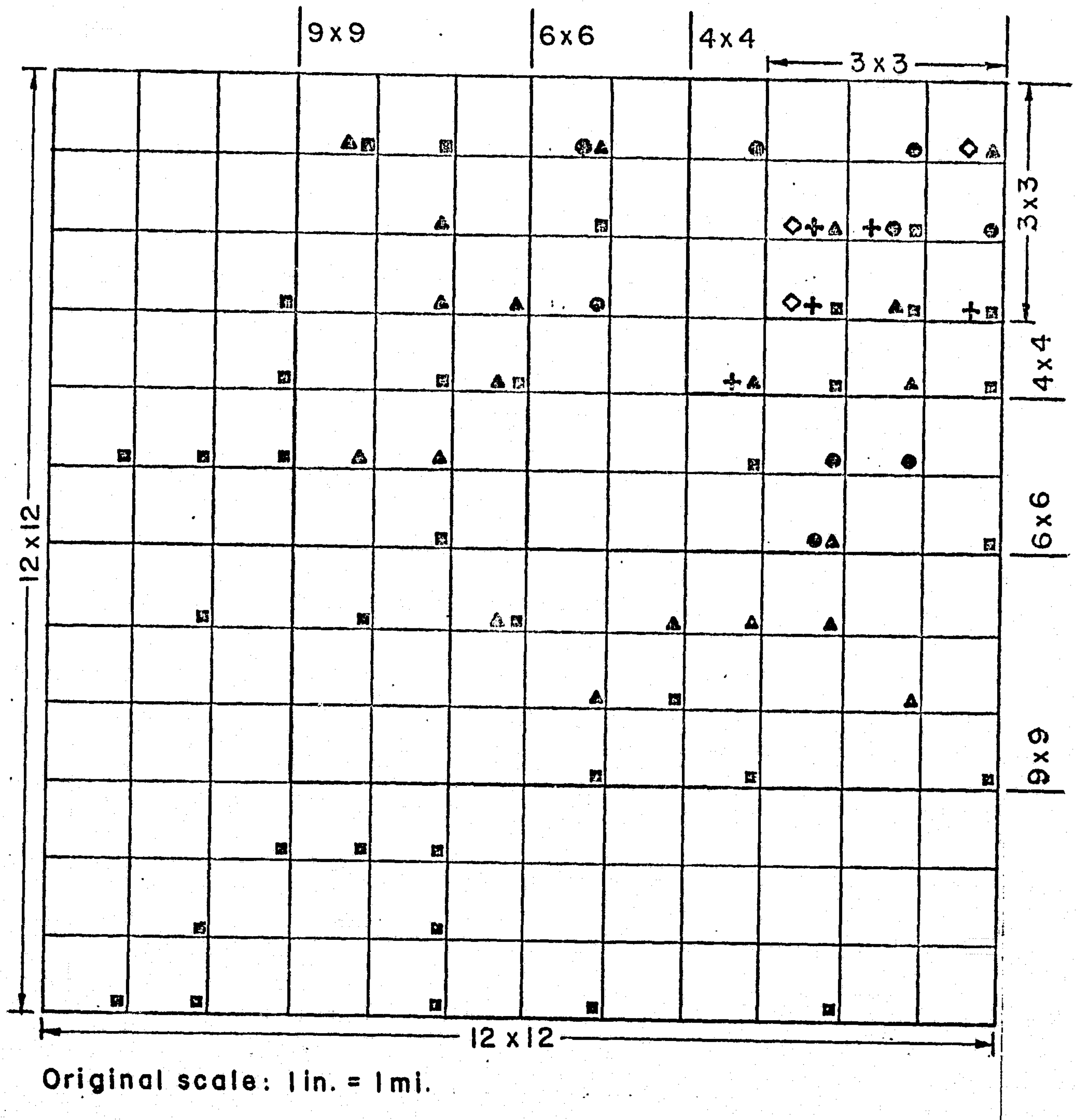


Figure 14. Grid matrices for a twenty-five percent random sample of various sized mapping units.

single sheet of acetate. Seven separate borderless squares representing each of the categories was mapped in columnar form on an acetate overlay. This permitted mapping all factors within the section sequentially, and provided a systematic basis for the subsequent densitometer measurement of areas. In this manner, level I mapping of a square mile section could be accomplished in approximately 7 to 15 minutes, depending on the number of categories present and pattern complexity. An illustration of these overlays is shown in Figure 15.

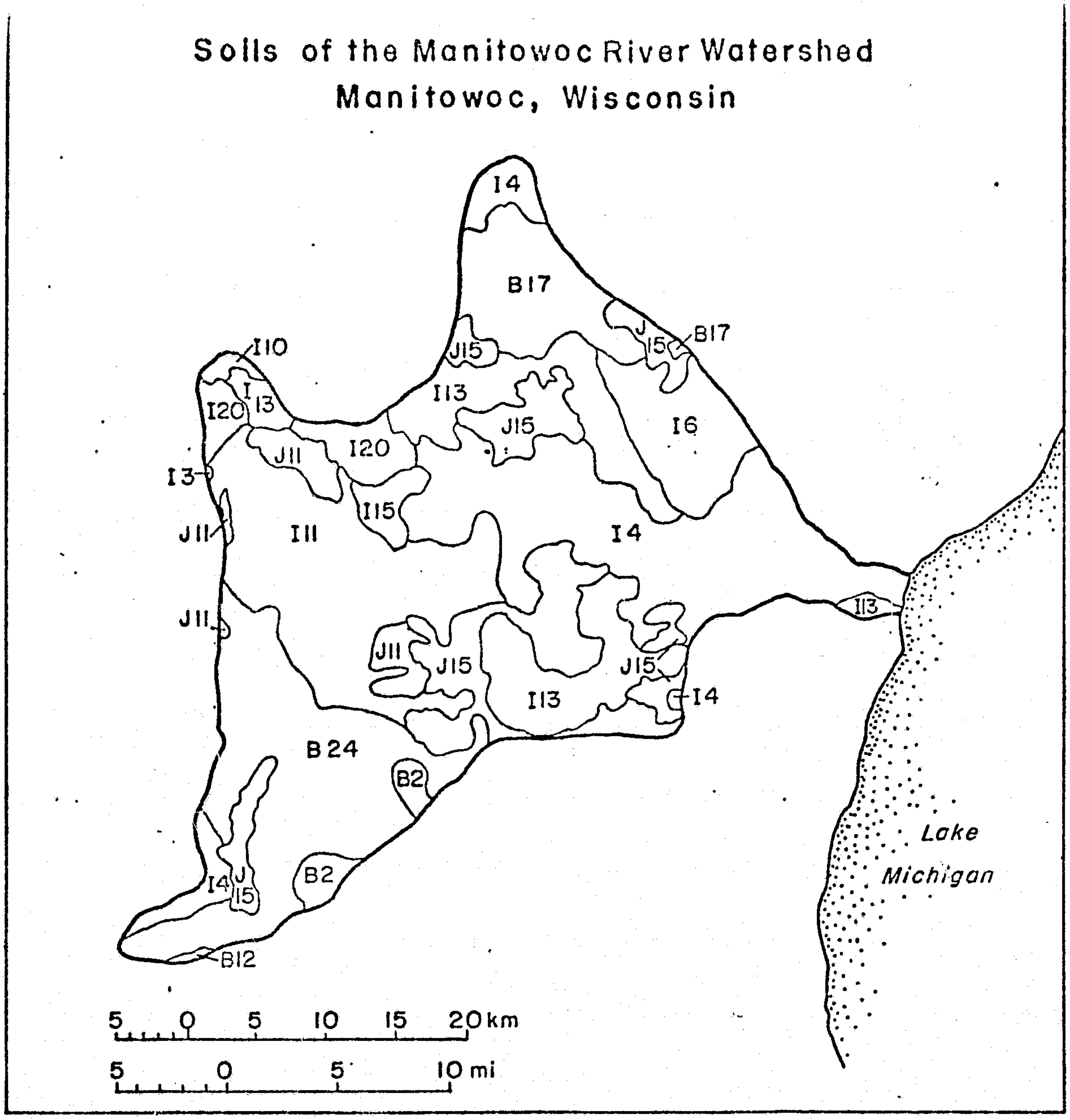
SOILS OF MANITOWOC, EAST TWIN AND OCONTO RIVER WATERSHEDS

Assessment of the soils was needed to examine the relationship among land use, soil, association and stream sedimentation. The soil information used in this investigation was obtained from soil surveys and maps prepared by the U. S. Department of Agriculture. Details on soil association, topography, parent material and classification according to the 7th approximation can be obtained from the Legend For Overlay Soil Map of Wisconsin (Wis. Geol. & Nat. History Survey, 1968).

Manitowoc River Watershed

The approximate percentages of the principal soil groups that occur in the Manitowoc River Watershed (Fig. 16) are: The Soils of the Southeastern Uplands (20%), Soils of the Northern and Eastern Clayey and Loamy Reddish Drift Uplands and Plains (50%) and Soils of the Stream Bottom and Major Wetlands (30%) (Fig. 13). The Southeastern Upland soils developed in loess and sand or loamy till and are located in the headwater area of the watershed. The parent material for the soils found on the Reddish Drift Uplands and Plains is primarily clay and

Figure 15. Example of separate overlay mapping for a single square mile section. Numbers refer to land use categories as shown in Appendix II.



Legend

B Soils of the Southeastern Upland

- B 2 - Hochheim, Teresa and Brookston silt loam
- B12 - Teresa, Hochheim and Nenno silt loam (rolling)
- B17 - Teresa, Onaway, Fox and Salter silt loam and loams
- B24 - Teresa, Hochheim amd Nenno silt loam (gently undulating)

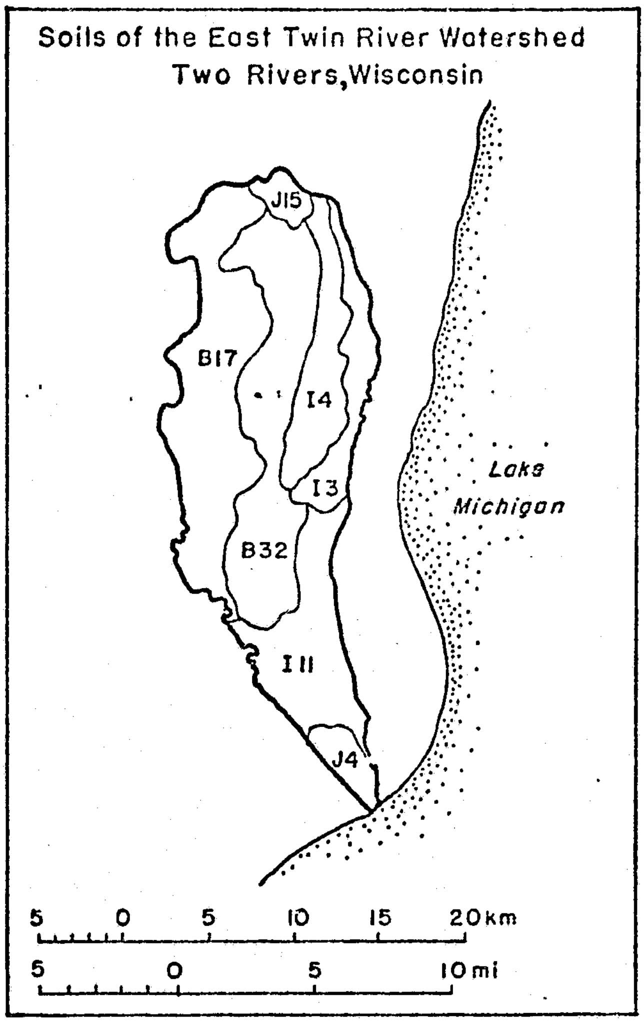
I Soils of the Northern and Eastern Clayey and Loamy Reddish Drift Uplands and Plains

- I 4 - Kewaunee, Hortonville, Manawa and Poygan silt loam and silty clay loam
- I 6 - Onaway loam: Teresa, Hortonville, Fox and Casco loams
- I10 - Kewaunee, Manawa and Poygan silty clay loam
- I13 - Kewaunee, Manawa, Poygan and Hortonville loams and silt loams: Tustin loamy sand
- I15 - Kewaunee, Kolberg and Manawa silt loam and loams
- I20 - Kewaunee, Oshkosh, Manawa and Poygan silty clay loam

J Soils of the Stream Bottoms and Major Wetlands

- J 4 - Newton, Plainfield and Norocco sand and loamy sand, and shallow peat soils
- J11 - Zittau, Poygan, Poy and Borth loams and silty clay loam
- J13 - Raw acid sedge and woody peat soils with thin moss covering; Cable and Freer silt loam
- J15 - Slightly acid to alkaline sedge and woody peat and muck soils; Pella, Poygan and Brookston silt loam and silty clay loam

Figure 16. Soil groups of the Manitowoc River watershed.



Legend

B Soils of the Southeastern Upland

B17 - Teresa, Onaway, Fox and Salter silt loam and loams
B32 - Piano and St. Charles (stratified substratum), Warsaw and Fox silt loam

I Soils of the Northern and Eastern Clayey and Loamy Reddish Drift Uplands and Plains.

I4 - Kewaunee, Hortonville, Manawa and Poygan silt loam and silty clay loam
I11 - Kewaunee, Manawa and Poygan silt loam and loams
I13 - Kewaunee, Manawa, Poygan and Hortonville loams and silt loam; Tustin loamy sand

J Soils of the Stream Bottoms and Major Wetlands

J4 - Newton, Plainfield and Morocco sand and loamy sand; shallow peat soils
J15 - Slightly acid to alkaline sedge and woody peat and muck soils; Pella, Poygan and Brookston silt loam and silty clay loam

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Figure 17. Soil groups of the East Twin River watershed.

silt. These soils occur in the central and lower reaches of the drainage system on 2-12% slopes. The Stream Bottom and Wetland Soils are located throughout the watershed on level plains and are usually poorly drained. The parent materials for these soils are glacial sandy outwash and organic materials, calcareous clayey lacustrine sediments and sandy and loamy glacial drift.

East Twin River Watershed

The same soils groups that appear in the Manitowoc Watershed occur in the East Twin River Watershed (Fig. 17) but the percentages differ as follows: Soils of the Southeastern Uplands (55%), the Northern and Eastern Clayey and Loamy Reddish Drift Uplands and Plains (40%) and Stream Bottom and Major Wetlands (5%) (Fig. 15). The distribution of these soils is similar to that of the Manitowoc.

Oconto River Watershed

The Oconto is the largest of the three watersheds (Fig.1) and contains the greatest number of soils. The approximate percentages of the principal soil groups are: the Soils of the Southeastern Upland (1%), the Soils of the Northern and Eastern Sandy and Loamy Reddish Drift Uplands and Plains (48%), the Soils of the Northern Silty Upland and Plains (5), Soils of the Northern Loamy Upland and Plains (22%), the Northern Sandy Upland and Plain (17%), and Stream Bottom and Major Wetland (7%) (Fig. 18). Generally the silty and loamy soils occur on moderate to steep slopes in the headwater regions. Coarse grained deposits are found in the gently rolling and level plain positions in

Legend

B Soils of the Southeastern Upland

B30 - Fox and Casco loams; Boyer sandy loam

E Soils of the Northern and Eastern Sandy and Loamy Reddish Drift Uplands and Plains

E 1 - Emmet loamy sand, Onaway loams; Omega loamy sand
E 2 - Onaway and Solona loams; Emmet and Underhill sandy loam; Angelica loams
E 4 - Onaway, Underhill, Emmet, Alban and Solona loams
E 5 - Solona, Onaway, Angelica and Wauseon loams
E12 - Shawano, Keowns, Granby and Au Gres loamy sand and sandy loam
E13 - Shawano and Granby loamy sand and sandy loam; peat and muck soils

F Soils of the Northern Silty Uplands and Plains

F 5 - Stambaugh and Goodman silt loam; Padus and Iron River loams
F 6 - Antigo and Norrie silt loam, Onamia and Kennan loams
F16 - Stambaugh silt loam, Padus and Iron River loams; peat soils
F25 - Antigo and Brill silt loam; Onamia loams

G Soils of the Northern Loamy Uplands and Plains

G 1 - Cogebic and Iron River loams, stony, with bedrock outcrops
G 2 - Iron River and Pence loams; Goodman, Monico and Stambaugh silt loam; peat soils; some areas are stony
G 3 - Iron River and Pence loams; Vilas sand, and peat soils
G11 - Iron River, Padus and Pence loams; Vilas sand, and peat soils
G16 - Padus and Pence loams; Omega sand, Stambaugh silt loam, and peat soils
G25 - Pence and Padus loams; Stambaugh silt loam; Vilas and Omega sand
G26 - Onamia and Chetek loams and sandy loam, Antigo silt loam, and peat soils
G27 - Pence sandy loam; Vilas sand; Stambaugh and Padus loams, and peat soils

H Soils of the Northern Sandy Uplands and Plains

H1 - Vilas, Omega and Hiawatha loamy sand and sand; Pence sandy loam, and peat soils
H2 - Vilas, Omega and Hiawatha loamy sand and sand, and peat soils
H4 - Omega and Vilas loamy sand and sand; Pence sandy loam, and peat soils
H6 - Omega and Vilas loamy sand and sand; Chetek and Pence sandy loam, and peat soils

J Soils of the Stream Bottoms and Minor Wetlands

J13 - Raw acid sedge and woody peat soils with thin moss covering; Cable and Fever silt loam
J14 - Acid sedge peat and muck soils; Au Gres, Newton and Morocco sand and loamy sand
J15 - Slightly acid to alkaline sedge and woody peat and muck soils; Pella, Poygan and Brookston silt loam and sandy clay loam

Figure 18. Soil groups of the Oconto River watershed.

the central portion of the watershed. Finer textured soils (silts and clays) are found in the lower reaches of the river.

WATER QUALITY DATA FROM MANITOWOC, EAST TWIN AND OCONTO WATERSHEDS

Water samples were taken in June and October 1973 and May 1974 as part of the ground truth for the NASA photo mission. Suspended solids were determined on all of the samples at USACRREL according to procedures used by the Wisconsin Department of Natural Resource, Division of Environmental Protection and the U. S. Department of Agriculture.

Manitowoc River

The field sample sites are located in Figure 19. The June 1973 suspended solids data vary from 30 mg/l to 105 mg/l with an average of 70.1 mg/l (Table 7). The precipitation immediately preceding and during the sampling period, 19-21 June, averaged 0.45 inches. During October the suspended solids in the Manitowoc River decreased to an average of 6.3 mg/l. The samples were obtained on 8 October and for the six days, 3-8 October, only 0.1 to 0.2 inches of precipitation occurred in the watershed. In May of 1974 the average amount of suspended solids in the river was 14.3 mg/l. For the six days up to and including the sampling date of 3 May the precipitation averaged 0.2 inches. The suspended solids data from the same monthly time periods from 1965-1968 indicate the same trend as the data obtained from this study (Tables 6 and 7.

East Twin River

Suspended solids determinations were made at four sample sites in the East Twin River (Fig. 19). The average suspended solids from the

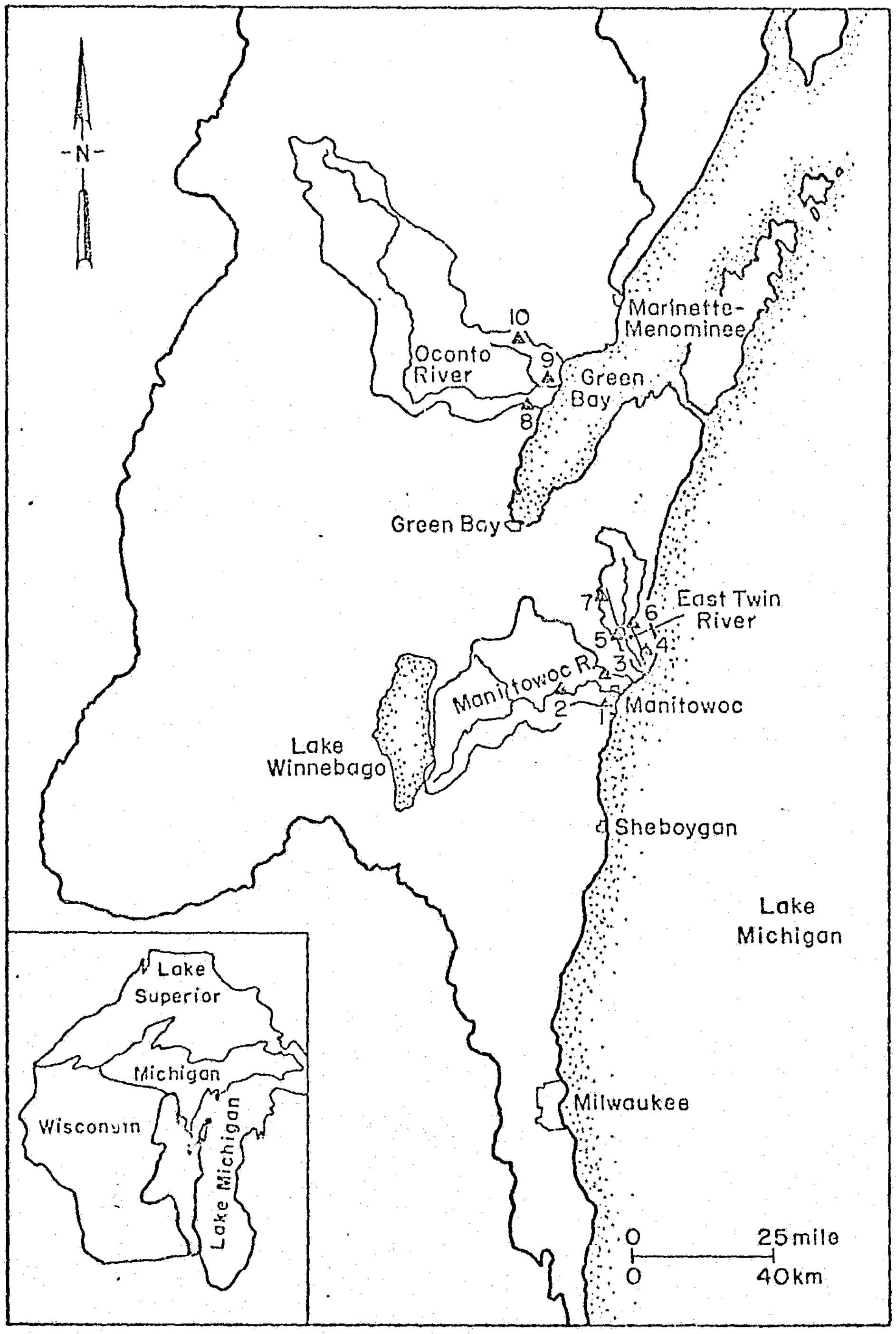

Figure 19. Field sampling sites for suspended solids.

TABLE 7. WATER QUALITY DATA: MANITOWOC RIVER

Sample	Turbidity (JTU)*	Suspended Solids (mg/l)	Organic Matter (mg/l)	Non-organic (%)	Organic (%)
1. June 1973					
(21)	43	81.8	25.4	69	31
(3)	39	29.8	9.6	69	32
(2)	18	63.4	18.6	71	29
(3)	52	105.4	16.2	85	15
		Ave. 70.1			
2. October 1973					
Hwy 141 (3)	2	5.0	-	-	-
Harbor (1)	5	7.6	-	-	-
		Ave. 6.3			
3. May 1974					
Harbor (1)	10	16.5	-	-	-
Mill Road (3)	10	16.9	-	-	-
Clark Mills (2)	2	10.3	-	-	-
		Ave. 14.3			

*JTU - Jackson Turbidity Units

TABLE 8. WATER QUALITY DATA: EAST TWIN RIVER

Turbidity (JTU)	Suspended Solids (mg/l)	Organic Matter (mg/l)	Non-organic (%)	Organic (%)
12	-	-	-	-
18	28.6	8.6	70	30
15	39.6	8.2	79	21
26	38.0	16.4	57	43
	Ave. 35.4			
20+	22.4	-	-	-
4	3.7	-	-	-
	Ave. 13.0			
2	4.08	-	-	-

73 sampling was 35.4 mg/l and precipitation during the preceding was 0.39 inches. The October data were collected on the eighth uspended solids and precipitation for 3-7 October averaged and 0.28 inches. The May sampling was taken on the third and 1 mg/l of suspended solids. The precipitation averaged 0.22 the six days from 28 April to 3 May. This data compared with that obtained by the Wisconsin Department of Natural (1965-1968).

Oconto River

The three water sampling sites for the Oconto River are shown in Figure 19. The 19 June 1973 samples yielded an average of 61.9 mg/l of suspended solids. The average precipitation during 14-18 June was 0.15 inches. In October 1973 and May 1974 the water samples collected contained very little suspended solids and much of this was in organic form. These data correspond to data taken during similar intervals in 1965-1969 (Wisconsin Dept. of Natural Resources 1968).

TABLE 9. WATER QUALITY DATA: OCONTO RIVER

ple	Turbidity (JTU)	Suspended Solids (mg/l)	Organic Matter (mg/l)	Non-organic (%)	Organic (%)
1973					
r	24	52.6	9.2	83	17
141	35	71.2	16.8	76	24
		Ave. 61.9			
er 1973					
141	2	2.2	1.5	59	41
974					
141	22	3.4	-	-	-
les	2	1.4	-	-	-
		Ave. 2.9			

LAND USE/STREAM SEDIMENTATION RELATIONSHIPS

The land use maps prepared from the NASA RB-57 imagery for the Manitowoc, East Twin River and Oconto watersheds indicate that the agricultural land comprises the majority of the land area in the Manitowoc and East Twin River, 74% and 66% respectively but only 27% in the Oconto; the major unit in the Oconto watershed is forest comprising 50% of the landscape. When these percentages are compared to the suspended solids data taken from the Manitowoc, East Twin and Oconto River watershed, the results show that as the percentage of agricultural land increases, the amount of sediment in the stream increases (Table 10).

TABLE 10. LAND USE, SUSPENDED SOLID, SOILS AND PRECIPITATION DATA FOR THE MANITOWOC, EAST TWIN, AND OCONTO RIVER WATERSHEDS

Watershed	Total Acres	Agr (open) (%)	Agr closed (%)	Forest (%)	Urban (%)	Wetlands and Water (%)	Other (%)	Suspended Solids Average mg/1	Soil Texture	Precip. Five Days Preceding Mission (inches)
Manitowoc	368,380	35	39	17	2	5	2	14.6	Fine	0.2
East Twin	88,264	36	30	18	5	2	9	4.1	Medium to fine	0.2
Oconto		18	9	50	1	16	6	2.4	Coarse	0.1

Supporting data for this relationship also can be found in the soils data. The finer textured soils and the largest percentage of these soils can be found in the Manitowoc Watershed. The headwater area of the East Twin contains medium to fine grained surface sediment but toward the

mouth of the river there are finer grained soils. However, in the Oconto the soils are primarily developed in sandy and loamy deposits which are very coarse grained. Also, in this watershed there is a large percentage of organic soils so the suspended solids would consist of a large percentage organic matter. These data reveal that the Manitowoc Watershed has the greatest percentage of agricultural land, the finest textured soils and had the largest amount of particulate matter in the stream (Fig. 20) during the test, and the Oconto has the least percentage of agricultural land, the coarsest textured soils and the lowest amount of suspended solids in the stream (Fig. 21). The precipitation data also supports these findings. During the five days before the 1974 photography and ground truth mission there was more rainfall in the Manitowoc River watershed and the least amount recorded was in the Oconto River watershed (Table 6, Appendix I).

To provide a more direct basis for comparing water quality parameters to signatures contained in remote sensing imagery, multispectral measurements of reflected and incident light were made in conjunction with water sampling during Mission 235. An Exotech ERTS Ground Truth Radiometer was employed.

Multiple correlation analysis indicated that reflectivity of the streams sampled is related linearly to incident and reflected radiation in ERTS MSS band 5 (Fig. 22). A multiple correlation coefficient (R) of 0.85 and a standard error of estimate for suspended solids in streams of 3.8 mg/l was obtained. The measurement and estimated values are shown in Table 11. The range of suspended solid concentration during the test

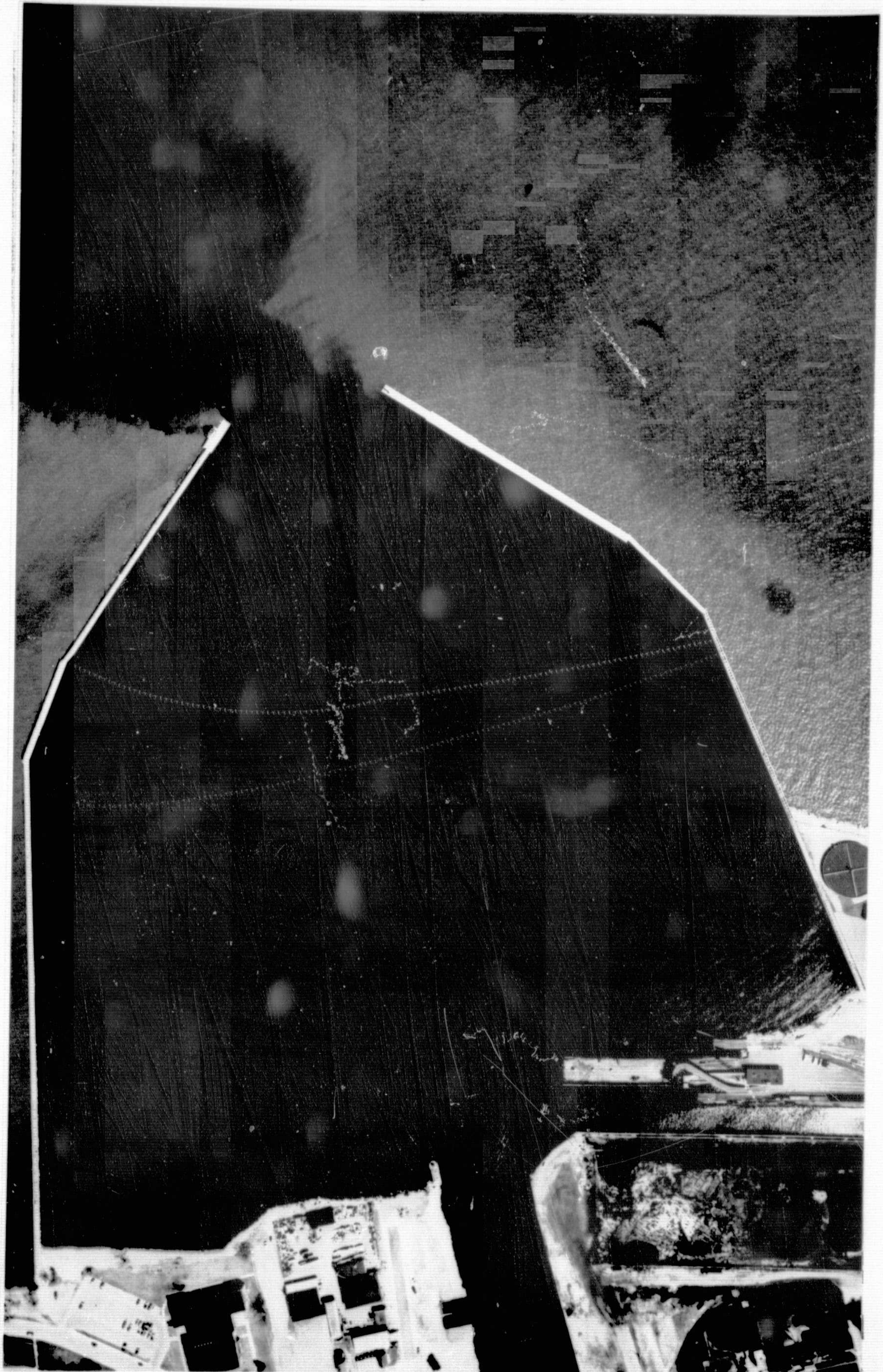

Figure 20. Manitowoc River and harbor

Figure 21. Oconto River at Oconto

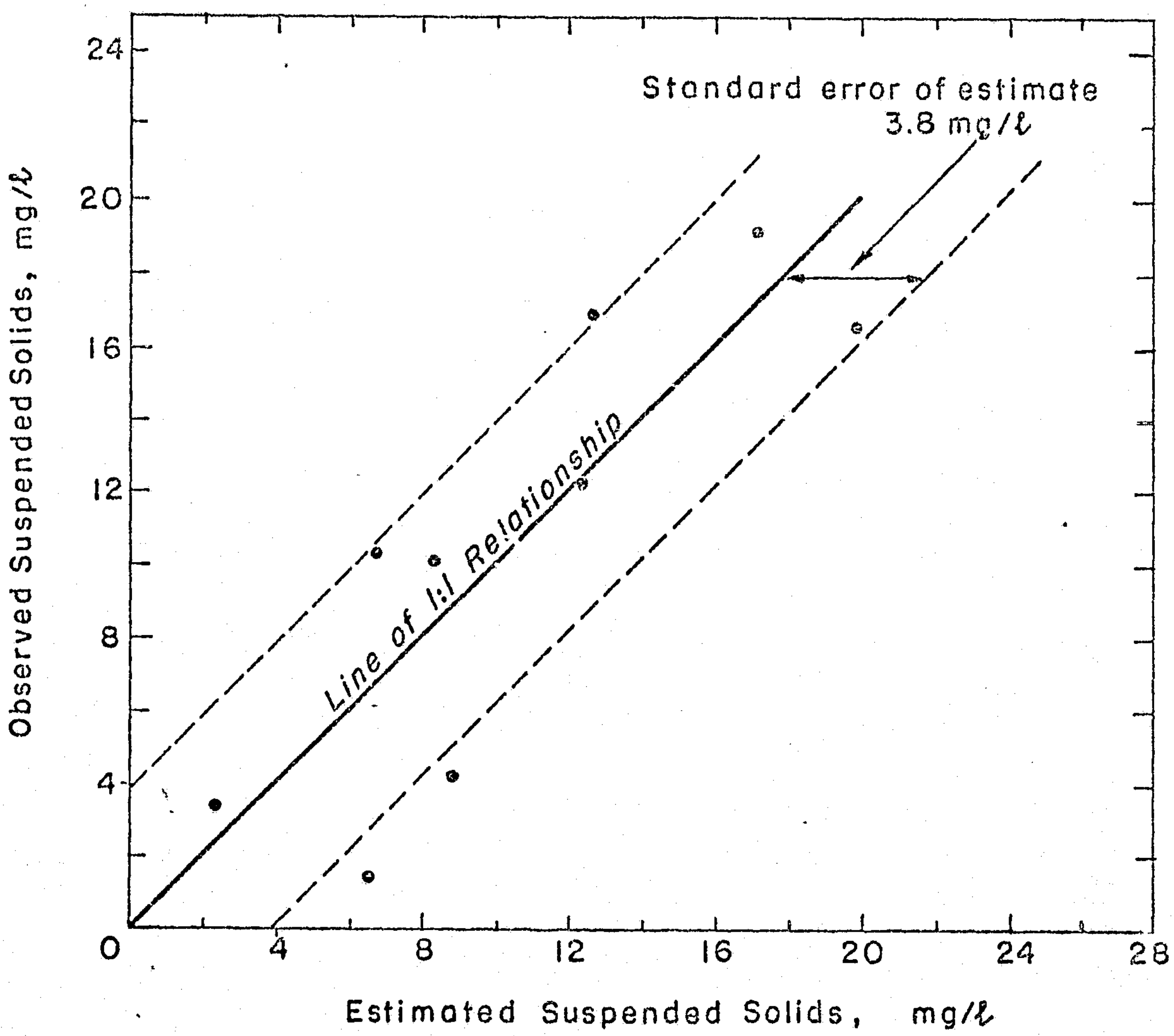

Figure 22. Relationship of ERTS MSS band 5 incident and reflected radiation to measured suspended solids.

TABLE 11. COMPARISON OF SPECTRAL MEASUREMENTS[1] AND SUSPENDED SEDIMENT LOAD AT WATER SAMPLING SITES.

Stream/Sampling Site	Date/ Local Time	Reflected Radiation Band 1	2	3	4	Incident Radiation[2] Band 1	2	3	4	Suspended Solids (Mg/l) Measured	Est.[3]
Oconto River Hwy 141	2 May 74 1530	.04	.05	.03	.00	.30	.38	.30	.34	3.4	2.16
Oconto River Stiles	2 May 74 1600	.10	.12	.08	.04	.30	.40	.32	.36	1.4	6.24
Manitowoc River Clark's Mills	3 May 74 1120	.12	.20	.10	.02	.58	.70	.18	.08	10.3	6.89
Manitowoc River Mill Road	3 May 74	.22	.32	.18	.08	.66	.82	.64	.64	16.9	12.65
Manitowoc River Harbor	3 May 74 1300	.30	.42	.20	.08	.56	.80	.64	.80	16.5	19.19
East Twin River Mishicot	3 May 74 1330	.14	.24	.14	.06	.60	.74	.60	.78	4.08	8.81
Fox River Wrightstown	3 May 74 1030	.16	.24	.14	.00	.16	.16	.16	.60	19.1	17.22
Fox River Green Bay	2 May 74 1315	.16	.20	.11	.00	.28	.32	.24	.28	12.2	12.40
East Twin River Photo	3 May 74 1500	.16	.20	.08	.02	.46	.60	.46	.56	10.1	8.34

[1]Spectral Range of Bands: 1 (0.5-0.6μ); 2 (0.6-0.7μ); 3 (0.7-0.8μ); 4 (0.8-1.1μ)

[2]Reflectance measurements are based on a 2 milliwatt full scale reading ($2 mw/cm^2$); incident measurements are based on a 10 milliwatt full scale reading ($10 mw/cm^2$)

[3]Estimated according to Eq. $y = 4.54 + 62.5X_1 - 14.5X_2$, where y = estimated suspended solids (Mg/l), X_1 = reflected 0.6-0.7μ radiation ($mw/cm^2 x5$), X_2 = Incident 0.6-0.7μ radiation (mw/cm^2)

period was low, 2-20 mg/l, but the high correlation with radiated and incident light measurements suggests that the relationship would also exist for higher concentrations of suspended sediment in the streams. Further sampling of a wider range of suspended sediment concentrations with concurrent incident and radiated light measurements would permit the estimation of stream sediment loads based on digital density measurements of remote sensing imagery in the .6-.7 micron wavelength for this test area.

A trial application of the Universal Soil Eoss equation (USDA, 1965) did provide estimates of soil loss that correlated with observable and measurable differences in turbidity of the East and West Twin Rivers, but it was apparent that refinement was necessary for the input data to the Universal Soil Loss Equation to provide meaningful results for the variety of streams in the test area. It is believed that this could be accomplished with further work, based on imagery and other soil data.

RESULTS AND CONCLUSIONS

The primary focus of this investigation has been to examine the feasibility of using remote sensing methods to rapidly and economically assess, on a regional scale, the effect of land use as it influences sediment loading of streams. A test area, consisting of several major watersheds in Eastern Wisconsin, was selected for the development and evaluation of techniques to achieve this objective.

A wide variety of aerial remote sensors was applied to the test area for evaluation and development of data pertinent to the assessment of the relationships between land use patterns and the sediment load in streams. By far the most useful imagery supplied by NASA for the investigation was the color infrared acquired at 60,000 feet with 9 inch format RC-8 and Zeiss cameras. This combination of sensors was judged to be adequate for any regional scale land use mapping effort to level II of the USGS land use classification, and, with appropriate ground truth support, level III detail is feasible.

Sensor evaluation includes the following:

High Altitude RS-7 Thermal Scanner - This imagery, acquired during daylight hours from an altitude of 60,000 feet provided a small scale (1:1,000,000) thermal map of much of the study area. General land use patterns could be observed as well as large water circulation patterns in Lake Michigan and Green Bay. The apparent swath of a recent rain shower could be readily located on the landscape. The only man-made effluent identified were thermal plumes from a nuclear power plant. The detection and mapping of major circulation patterns in large water bodies would be the primary recommended application for this sensor for high altitude operation.

High Altitude Multi-spectral 70 mm (Hasselblad) Photography - This sensing tool did not provide significant data input for the study. The small 70 mm format is difficult to work with, and the multispectral and color infrared imagery acquired with the Hasselblads did not contain any information that was not more easily obtained from the 9 inch format

cameras. Although the acquisition cost of 70 mm imagery would be somewhat less than 9 inch format imagery, interpretation for most purposes is more difficult and time consuming and would probably offset any economy gained by the lower original cost. This is also true of the multispectral photography acquired at 5,000 feet by the investigators with a 4 camera Hasselblad system.

High Altitude Color (SO 397) - This imagery was usable for most purposes of this study, but was surpassed in utility by the 9 inch format color infrared (2443) emulsion. A major effort was made during the course of the study to correlate stream color differences apparent in the color imagery with water quality parameters, such as suspended sediment load and chemical pollution. Densitometric determination of Munsell color equivalents were determined at a large number of sample points. The results of this effort were considered indecisive because 1) the general color balance of the imagery provided varied widely from flight to flight, 2) the loss of density detail as compared to originals on the duplicate imagery provided by NASA, and 3) the influence of many uncontrollable variables on photographic color such as the angle and intensity of sunlight and atmospheric haze. It is believed the method could be developed to apply to small areas, single flight line surveys, but does not appear feasible for regional area surveys or with high altitude imagery.

PMIS - The PMIS (Passive Microwave Imaging System) imagery was acquired on Mission 235 on the Fox River valley at an altitude of 4300 feet. Because PMIS is a new sensor, and few terrestrial applications have been demonstrated for it, considerable effort was devoted

to the interpretation and evaluation of the imagery. Other than land-water boundaries, it was not possible to consistently identify major patterns on a 64 color photographic rendition of the PMIS scanning data. Further, exhaustive attempts to correlate individual segments of the PMIS scan between the computer-generated false color imagery and the digital computer printout provided were unsuccessful. Signatures of individual scan segments could be correlated with photographic color infrared imagery, however, for some types of features such as large buildings with metal roofs or small impoundments in agricultural areas. There are severe limitations concerning the PMIS as a remote sensing tool for terrestrial phenomena in the eastern Wisconsin test area. In addition to scan line identification and correlation difficulties, the sensor at the altitude flown has poorer spatial resolution than an ERTS MSS pixel, coupled with a comparatively narrow field of view. Although more detailed processing at the PMIS ground data station and imagery acquired at a lower altitude would provide more detail, it appears unlikely that this sensor could provide data for land use mapping comparable in quality or utility to the more readily available thermal scanning or photographic sensors. The PMIS sensor was originally designed for the microwave imaging of water surface characteristics, an application that was not tested in this investigation. For these applications, PMIS may well be the best sensor available. However, problems relating to image correlation and resolution would still appear to apply.

RS-14 Thermal Scanner - This imagery in the 8-14 micron range was acquired during Mission 272 at altitudes ranging from 2500 to 3500 feet of the Wisconsin shoreline and several watershed areas. It was compared for information content with color infrared photographic imagery obtained during other missions. Analysis indicated that many of the patterns displayed on the thermal imagery are readily detectable on color infrared or color imagery. This information included effluents in water bodies, detailed land use, soil moisture and drainage patterns, and urban patterns. Where actual temperature information is desired, there is no substitute for the thermal imagery. Recommended specialized applications include monitoring and mapping details of effluent plumes for size and concentrations, differentiation within wetlands, impervious areas in urbanized settings, or wherever relative temperature information is desired. For general mapping efforts, the lack of geometric control, narrow field of view, and high expense would appear to preclude the use of this sensor.

Land Use Analysis - The principal objectives of the land use analysis portion of this investigation were to develop a data base reflecting regional differences within the test area for comparison with stream sediment loading data, and to determine the most efficient and effective approaches to land use mapping based on the imagery provided by NASA.

The USGS Land Use Classification System for Remote Sensing was incorporated because it is widely used, is compatible with most other

commonly used classifications, and is sufficiently flexible to accommodate specialized applications. Although initial mapping efforts were confined to level I of the system, subsequent mapping incorporated levels II and III to provide more pertinent data on erosion potential of agricultural land.

The final mapping of the large watersheds of the Manitowoc and the Oconto was done using the twenty-five percent sampling approach. For greater efficiency of measurement, categories of land use were mapped sequentially in columnar form on a single sheet of frosted acetate, and directly from 1:120,000 color infrared imagery. In terms of measurement with the color densitometer, this was considered to be the most accurate and rapid approach to determining land use area of a watershed.

Following the final mapping, comparisons were made with the earlier strip mapping efforts of the Oconto and Manitowoc watersheds. Regional differences were noted. Strip mapping of the Oconto resulted in overestimation of the amount of agricultural land (56% vs. 27%) compared to the random sampling method. Forest was considerably underestimated, 28% vs. 50%. For the Manitowoc, however, the strip mapping approach produced a slight underestimate of agricultural land, 62% vs. 74%, and an overestimate of the forest category, 25% vs. 17%. The land use distribution of the Oconto watershed is probably typical of a dominantly forested area, where most of the agriculture is near the streams. In the Manitowoc watershed, where the agricultural potential is fully developed, the majority of the remaining forest is near the streams. The strip map

approach, therefore, has a built-in bias which can vary depending upon the land use development history and also the nature of the terrain. The application of this mapping approach should be confined to cases where prior information is obtainable on general distribution of land use types within the watershed. A flow diagram of the land use mapping effort is shown in Figure 23.

A cost effectiveness analysis was performed on the various land use mapping approaches. The results are summarized in Table 12 The strip mapping approach, using colored pencil on a single acetate overlay of original scale photography, provides the fastest method of obtaining land use measurements. Including analysis, .4 hours per square mile was required. For the areas sampled with a 25% random sample and a combined sequential overlay map as previously described, 1.1 and 1.3 hours were spent per square mile of sample. The 25% sample of the East Twin River Watershed required slightly more, 3.2 hours per square mile of sample because the mapping was done on separate overlays. The results of the cost effectiveness analysis are similar to those shown in a NASA sponsored study by Vegas (1973) although the mapping objectives were more general than this application.

Various approaches to the actual mapping of land use were tested, but all incorporated the USGS classification system. The ability to measure mapped areas rapidly was a first requirement for any of the mapping procedures. The measurement device in all cases was the planimeter component of a color densitometer. This required that all mapped categories be distinguishable on the basis of their gray scale density.

LAND USE MAPPING AND ANALYSIS

FLOW DIAGRAM

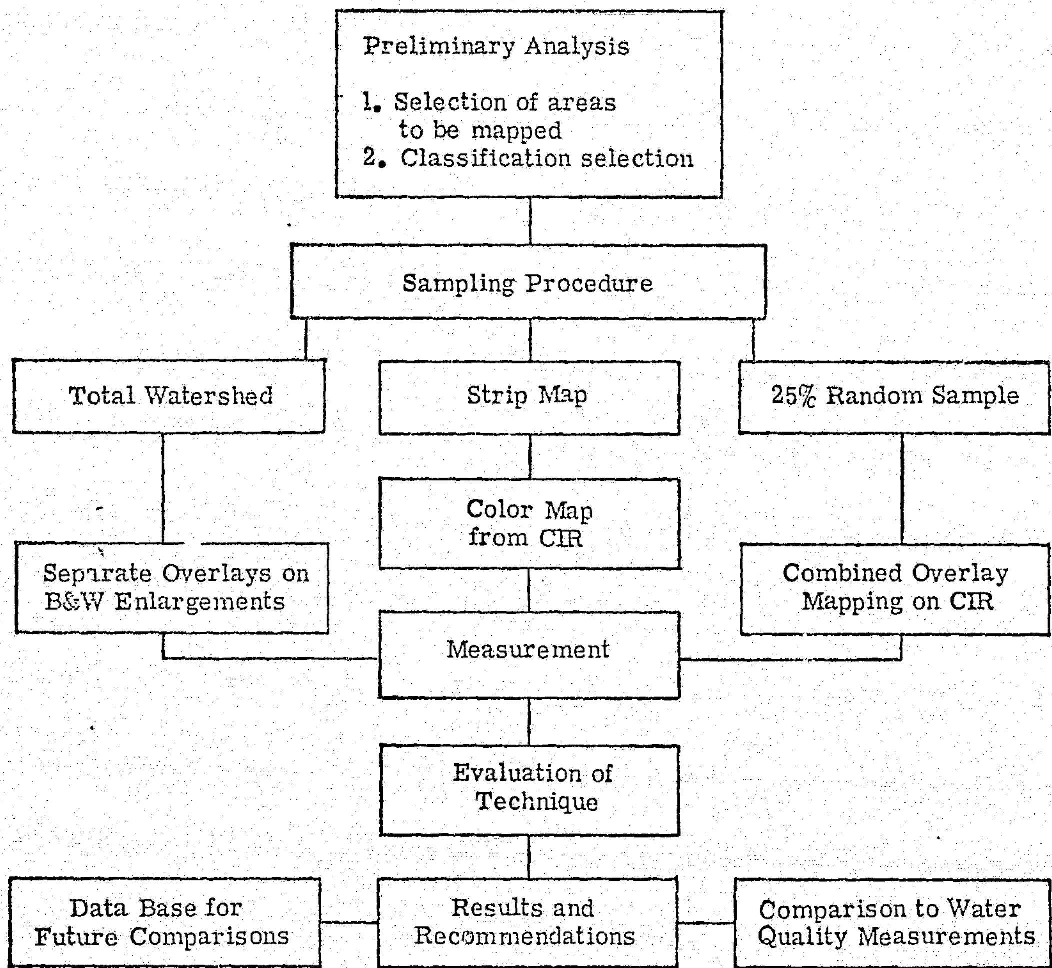

Figure 23. Flow diagram of land use mapping and analysis.

TABLE 12. COST EFFECTIVENESS ANALYSIS

	East Twin		Manitowoc	Oconto	
	25%	Total	25%	25%	Strip
Enlargements	1.5	1.5	2	3	-
Overlays	4	4	8	8	-
Sampling	8	-	20	20	16
Mapping Separate	29	65	-	-	-
Combined	-	-	120	155	40
Measurement	8	12	30	35	35
Tabulation of Data	4	16	20	30	10
Analysis	60	60	60	60	30
Hours/ No. of Sq. Mile Samples	114.5/ 36	158.5/ 144	260/ 150	311/ 250	131/ 344
Hours/ Square Mile	3.2	1.1	1.7	1.2	0.4

The first large watershed map to be produced was of the East and West Twin Rivers watershed. This mapping was done in color on frosted acetate and included only Level I of the USGS classification. Measurement with the densitometric planimeter was done according to a grid system previously described. A concurrent attempt was also made to measure land use categories directly from color or color infrared imagery using the densitometric method. This method worked for Level I mapping categories only in limited areas with light toned soils.

The second method applied to obtain land use data involved sampling rather than mapping the entire watershed. Colored acetate strip maps were made of two large watersheds, the Manitowoc and the Oconto. The sampling grid was constructed so that the sample included at least one mile of land on either side of any stream. This comprised approximately one third of the entire watershed area.

The third method involved a dual approach; one watershed, the East Twin River, was mapped in its entirety on six separate clear acetate overlays. The mapping was accomplished in ink to simplify the densitometric measurement. The land use of this watershed was measured first for the entire watershed, then on the basis of a 25 percent random sample. The results of this comparison were that all of the major mapping categories (Agriculture closed, Agriculture open, and Forest) were within four percentage points of being equal. Larger differences were noted for categories such as Urban and Water where the area involved was quite small (see Appendix II). Based on this comparison, it was decided that for subsequent mapping efforts the 25% random sample approach would provide sufficiently accurate data; and result in greater efficiency.

The analysis of the relationship between stream sedimentation and land use practices indicated that the amount of suspended solids measured from water samples increased with the percentage of agricultural land within the watershed. Soils and precipitation data were also compared to the suspended solids measured for the various streams. The Manitowoc watershed had the greatest percentage of agricultural land, the finest textured soils, and the largest amount of particulate matter in the stream during the test. The Oconto had the least percentage of agricultural land and the coarsest textured soils, and the lowest amount of suspended solids in the stream.

The use of high altitude color or color infrared imagery to characterize sediment loading of individual streams did not appear practical in the quantitative sense. The effects of image duplicating, processing, photo color balance, atmospheric haze, and time of day of the imagery all serve to decrease the informational content of the high altitude aerial image. Major differences among the streams were observable in some of the imagery. The Oconto is dark on most scenes, probably reflecting the high organic and low suspended solid content of the stream. The East Twin and the Manitowoc are generally more turbid, and this appears in most of the imagery. Attempts to measure and characterize stream color differences using the Densitometer-Munsell system of notation (Rib, 1968) were not sufficiently consistent to be of value. However, a comparison

of multispectral measurements made with a hand held radiometer in conjunction with water sampling during Mission 235 was successful. A multiple correlation coefficient (R) of 0.85 was obtained between incident and reflected radiation in the ERTS MSS band 5 (.6-.7 micron) and measured suspended solids concentrations in the streams. A trial application of the universal soil loss equation (USDA, 1965) did provide estimates of soil loss that correlated with observable and measurable differences in turbidity of the East and West Twin Rivers, but it was apparent that refinement was necessary for the input data to the Universal Soil Loss Equation to provide meaningful results for the variety of streams in the test area. It is believed that this could be accomplished with further work, based on imagery and other soil data.

RECOMMENDATIONS AND APPLICATIONS

This investigation has addressed two primary areas of application for remote sensing techniques: 1) Mapping and quantification of land use, and 2) the relationship of land use to stream sedimentation.

The application for land use mapping based on aerial or satellite imagery has been well documented in the literature. Conflicting demands for land utilization resulting from normal economic growth together with the regulatory requirements of the many Congressional Acts indicate clearly that more data on land use will have to be generated and continually updated. The evaluation of a wide variety of imagery types in this study led to the conclusion that high altitude color infrared imagery was the most universally acceptable for the mapping and measure-

ment of land use types. Based on this imagery a rapid and cost effective approach to the mapping and measurement of land use categories was demonstrated. The basic mapping approach developed in this investigation is now a part of the Corps of Engineers Handbook on "Remote Sensing of the Environment (Haugen and Splett, 1974).

The comparison of land use to stream sedimentation demonstrated that a relationship could be shown based primarily upon data derived by remote sensing means. This type of data is necessary for the prediction of impact on streams and harbors of land use changes within a watershed. A major problem in defining a land use-stream sedimentation relationship was the sparseness of published water quality data, especially for streams away from major population centers.

The collection of data on water quality, especially sediment load, could be accomplished quickly and with minimum expense if a data bank were developed which would include incident/reflected radiation measurements with each water sample made. With an adequate sampling over a regional area and throughout a representative range of national conditions, monitoring of stream sediment loads by remote sensing methods could be instituted as a practical and efficient technique.

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Appendix 1

Precipitation and Temperature Data

East Twin Watershed and bordering stations

Precipitation (inches)

October 1973

Station	3	4	5	6	7	8	9	10	11	12
Green Bay	T	.43	--	.01	--	--	.63	.02	.19	.06
Kewaunee	--	--	--	--	--	--	--	--	--	--
Two Rivers	T	.09	--	--	.04	--	--	--	.80	.03

Temperature (°F)

October 1973 (max/min)

Station	3	4	5	6	7	8	9	10	11	12
Green Bay	75/46	64/44	69/41	67/44	62/54	74/54	73/59	81/62	79/61	70/52
Kewaunee	--	--	--	--	--	--	--	--	--	--
Two Rivers	62/47	61/42	70/40	69/46	60/59	64/53	61/55	66/54	67/53	67/57

ment of land use types. Based on this imagery a rapid and cost effective approach to the mapping and measurement of land use categories was demonstrated. The basic mapping approach developed in this investigation is now a part of the Corps of Engineers Handbook on "Remote Sensing of the Environment (Haugen and Splett, 1974).

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The collection of data on water quality, especially sediment load, could be accomplished quickly and with minimum expense if a data bank were developed which would include incident/reflected radiation measurements with each water sample made. With an adequate sampling over a regional area and throughout a representative range of national conditions, monitoring of stream sediment loads by remote sensing methods could be instituted as a practical and efficient technique.

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East Twin Watershed and bordering stations

Precipitation (inches)

1974

Station	April 28	April 29	April 30	May 1	May 2	May 3	May 4	May 5	May 6	May 7
Two Rivers	.10	--	.14	--	--	.03	--	.35	.07	--
Kewaunee	--	--	--	--	--	--	--	.89	--	--
Green Bay	--	T	--	--	T	.17	00	1.15	--	--

Temperature ($^{\circ}F$)

May 1974 (max/min)

Station	29	30	31
Two Rivers	60/46	60/45	66/47
Kewaunee	61/47	55/44	65/45
Green Bay	65/49	61/44	69/49

C 2

E77-10148

East Twin Watershed and bordering stations

Precipitation (inches)

June 1973

Station	14	15	16	17	18	19	20	21
Kewaunee	--	.08	--	.20	.10	--	.05	--
Green Bay	--	.26	.04	.05	--	T	.01	.15
Two Rivers	--	T	.15	.01	--	--	.06	--

Temperature (°F)

June 1973 (max/min)

Station	14	15	16	17	18	19	20	21
Green Bay	83/55	80/58	80/58	80/59	80/56	82/63	77/58	73/58
Kewaunee	73/54	68/54	64/50	60/50	66/49	72/53	77/58	74/56
Two Rivers	69/53	67/54	70/54	65/50	62/49	67/51	73/51	75/47

E77-10148

TABLE 2

Precipitation and Temperature Data for Manitowoc River Watershed

Precipitation (inches)

1972

Station	May 29	May 30	May 31	June 1	June 2	June 3	June 4
Appleton	.49	.35	--	--	--	.05	--
Brillion	--	.77	.01	--	--	.60	.68
Chilton	.23	.61	--	--	--	.28	T
Green Bay	.06	.13	--	.01	--	.07	--
Manitowoc	.22	.58	--	--	.03	--	.02

Temperature (°F)

1972
(max/min)

Station	May 29	May 30	May 31	June 1	June 2	June 3	June 4
Appleton	71/50	56/44	68/40	79/53	81/54	85/61	75/56
Chilton	83/64	71/43	67/39	79/52	85/55	84/60	78/52
Green Bay	74/48	58/41	71/39	83/53	83/50	88/55	75/52
Manitowoc	67/55	65/42	65/41	80/43	77/52	82/54	81/55

E77-10148

Manitowoc Watershed and Bordering Stations

Precipitation (inches)

June 1973

Station	14	15	16	17	18	19	20	21
Appleton	--	.20	.05	.10	--	--	.05	.08
Brillion	--	--	.35	.10	.11	--	.05	--
Chilton	--	T	.25	.15	--	--	.05	--
Green Bay	--	.26	.04	.05	--	T	.01	.15
Manitowoc	--	--	.15	.03	--	--	.04	--

Temperature (°F)

June 1973 (max/min)

Station	14	15	16	17	18	19	20	21
Appleton	81/58	80/65	82/58	78/58	78/56	80/61	73/61	70/61
Chilton	84/52	83/53	84/64	81/63	80/53	81/61	81/53	75/55
Green Bay	83/55	80/58	80/58	80/59	81/56	82/63	77/58	73/58
Manitowoc	81/55	72/54	80/55	70/54	69/52	84/51	82/57	76/57

Manitowoc Watershed and Bordering Stations

Precipitation (inches)

October 1973

Station	3	4	5	6	7	8	9	10	11
Appleton	T	.11	--	.02	.02	--	.82	.02	.50
Brillion	.18	.05	--	--	.07	--	--	.18	.86
Chilton	--	.20	--	--	.10	--	.15	.05	.75
Green Bay	T	.43	--	.01	--	--	.63	.02	.19
Manitowoc	.02	.07	--	--	.21	--	--	--	--

Temperature (^{o}F)

October 1973 (max/min)

Station	3	4	5	6	7	8	9	10	11	12
Appleton	73/55	64/47	68/43	62/48	61/52	73/55	71/62	78/63	78/63	70/55
Chilton	73/48	72/50	68/46	67/41	62/51	70/53	73/60	79/60	78/62	72/60
Green Bay	75/46	64/44	69/41	67/44	62/54	74/54	73/59	81/62	79/61	70/52
Manitowoc	67/50	61/52	69/42	64/41	61/52	67/60	64/59	69/59	69/61	67/59

Manitowoc Watershed and Bordering Stations

Precipitation (inches)

1974

Station	28	29	30	1	2	3	4	5	6	7
Appleton	--	.03	--	--	T	.04	--	.35	.02	--
Brillion	--	--	--	--	--	.04	--	--	.59	--
Chilton	--	--	--	--	--	--	--	.11	.16	--
Green Bay	--	T	--	--	T	.17	--	1.15	--	--
Manitowoc	--	T	--	--	--	.03	--	.28	.09	--

Temperature (^oF)

May 1974 (max/min)

Station	29	30	31
Appleton	68/54	65/49	69/51
Brillion	--	--	--
Chilton	66/55	68/45	68/51
Green Bay	65/49	61/44	69/49
Manitowoc	67/55	61/46	74/49

TABLE 3

Precipitation and temperature data for Oconto River Watershed

Precipitation (inches)

1972

Station	May 29	May 30	May 31	June 1	June 2	June 3	June 4
Breed	.10	.56	--	--	--	--	--
Crivitz High Falls	--	1.40	--	--	--	--	--
Lakewood	.80	.18	--	T	T	--	--
Oconto	T	.39	--	--	.05	--	--
Shawano	.27	.06	--	--	--	--	--

Temperature (°F)

1972 (max/min)

Station	May 29	May 30	May 31	June 1	June 2	June 3	June 4
Breed	84/60	67/41	70/28	82/42	82/44	89/47	89/39
Crivitz High Falls	86/68	72/42	68/36	72/46	76/48	76/50	86/49
Lakewood	79/52	75/40	70/30	81/47	81/46	87/50	82/43
Oconto	73/42	58/34	68/43	--	85/47	81/51	90/49
Shawano	84/51	67/42	72/32	80/48	84/46	88/45	87/44

Oconto Watershed and bordering stations

Precipitation (inches)

June 1973

Station	14	15	16	17	18	19	20	21
Breed	--	--	T	.14	.03	.04	.11	--
Crivitz High Falls	--	--	T	--	--	T	.10	--
Lakewood	--	.04	T	.46	--	--	.03	.03
Oconto	--	--	T	.05	.12	--	.03	--
Shawano	--	--	--	T	--	.06	.04	--

Temperature (°F)

June 1973 (max/min)

Station	14	15	16	17	18	19	20	21
Breed	85/49	85/47	83/61	75.54	78/56	84/60	83/57	75/51
Crivitz High Falls	94/60	86/62	89/66	80/55	71/54	73/60	82/58	76/56
Lakewood	83/45	83/59	75/58	73/51	75/56	81/60	78/55	73/52
Oconto	78/50	83/55	81/60	72/56	74/57	75/59	80/57	72/54
Shawano	81/48	80/57	75/64	78/53	78/53	76/54	80/61	80/51

Oconto Watershed and bordering stations

Precipitation (inches)

October 1973

Station	3	4	5	6	7	8	9	10	11	12
Breed	T	.17	.06	--	.07	--	--	.22	.56	.19
Crivitz High Falls	--	.32	--	--	T	--	.54	1.10	.10	--
Lakewood	--	.10	--	--	.03	--	.84	.09	.15	.03
Oconto	--	.10	.36	--	.07	--	--	.39	.27	--
Shawano	--	.11	--	--	.05	--	1.09	--	.29	--

Temperature (^{o}F)

October 1973 (max/min)

Station	3	4	5	6	7	8	9	10	11	12
Breed	75/40	72/49	68/29	70/28	62/49	73/54	73/59	76/52	78/56	75/60
Crivitz High Falls	73/40	74/42	72/30	70/29	73/33	70/60	66/54	75/58	75/64	72/54
Lakewood	73/40	70/47	68/32	65/30	60/48	72/52	68/57	70/58	74/60	68/58
Oconto	65/44	73/44	65/37	70/37	65/37	62/52	69/55	66/59	77/59	75/62
Shawano	73/49	70/45	69/30	68/30	60/46	72/49	72/54	76/55	78/53	78/53

Oconto Watershed and bordering stations

Precipitation (inches)

1974

Station	April 28	April 29	April 30	May 1	May 2	May 3	May 4	May 5	May 6	May 7
Breed	.03	.07	.03	.06	--	.22	--	.10	.23	--
Crivitz High Falls	T	T	--	.04	--	.31	--	.04	T	--
Lakewood	.12	.03	T	--	--	--	--	.26	.02	--
Oconto	--	--	--	T	--	.16	--	.18	.36	--
Shawano	--	--	--	--	--	.03	--	.55	.04	--

Temperature (°F)

May 1974

Station	29	30	31
Breed	72/53	72/37	71/47
Crivitz High Falls	75/57	71/44	70/45
Lakewood	73/55	65/40	70/46
Oconto	68/54	69/44	59/47
Shawano	68/55	68/47	70/49

Appendix II

Planimetric Densitometer Measurements

Planimetric Densitometer Readings
for 1972 Strip Map
Manitowoc River Watershed
Manitowoc, Wisconsin

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other
1	3.8	0	0	85.7	10.5
2	21.1	24.1	9.2	40.5	5.1
3	29.4	39.5	19.0	4.7	7.4
4	30.6	41.2	19.5	0	8.7
5	36.0	35.0	22.9	0	6.1
6	33.9	31.8	18.1	10.4	5.8
7	38.2	41.9	14.2	0	5.7
8	7.3	19.7	69.9	0	3.1
9	29.5	36.1	23.7	3.2	7.5
10	34.4	37.2	22.3	0	6.1
11	11.7	33.3	51.1	0	3.9
12	10.2	25.7	58.3	0	5.8
13	33.1	38.9	23.5	0.2	4.3
14	30.9	33.8	12.2	18.1	5.0
15	39.9	40.6	14.8	0	4.7
16	25.8	33.5	34.2	1.1	5.4
17	27.5	38.1	27.6	0	6.8
18	25.9	46.6	18.7	1.2	7.6
19	36.4	38.8	17.9	2.6	4.3
20	26.2	29.8	37.8	0	6.2

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other
21	26.1	39.0	28.0	0	6.9
22	28.6	32.9	30.3	0	8.2
23	19.3	45.5	29.1	0	6.1
24	25.8	35.0	32.0	0	7.2
25	31.7	44.0	18.5	0	5.8
26	32.9	52.0	8.0	0	7.1
27	28.2	33.8	30.6	0	7.4
28	35.9	42.1	13.6	0	8.4
29	33.8	34.3	25.5	0	6.4
30	28.5	54.8	10.6	0	6.1
31	32.7	44.9	18.4	0	4.0
32	29.9	36.9	28.4	0	4.8
33	23.6	44.9	26.4	0	5.1
34	37.7	49.3	7.7	0	5.3
35	26.1	39.3	5.2	23.4	6.0
36	26.7	48.5	18.9	0	5.9
37	37.3	46.1	6.8	1.3	8.5
38	18.1	42.6	31.2	0	8.1
39	30.7	36.2	27.9	0	5.2

Acres per Land Use Category
for 1972 Strip Map
Manitowoc River Watershed
Manitowoc, Wisconsin

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other	Total Acres in Sample Box
1	194	0	0	4388	538	5120
2	1080	1234	471	2074	261	5120
3	1505	2022	973	241	379	5120
4	1567	2109	998	0	446	5120
5	1843	1792	1172	0	313	5120
6	1736	1628	927	532	297	5120
7	1956	2145	727	0	292	5120
8	374	1009	3579	0	158	5120
9	1510	1848	1213	164	385	5120
10	1761	1905	1142	0	312	5120
11	599	1705	2616	0	200	5120
12	522	1316	2985	0	297	5120
13	1695	1992	1203	10	220	5120
14	1582	1730	625	927	256	5120
15	2043	2079	758	0	240	5120
16	1321	1715	1751	57	276	5120
17	1408	1951	1413	0	348	5120
18	1326	2386	957	62	389	5120
19	1864	1987	916	133	220	5120
20	1341	1526	1935	0	318	5120

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other	Total Acres in Sample Box
21	1336	1997	1434	0	353	5120
22	1464	1684	1551	0	421	5120
23	988	2330	1490	0	312	5120
24	660	896	879	0	185	2560
25	406	563	237	0	74	1280
26	421	666	102	0	91	1280
27	361	432	392	0	95	1280
28	460	539	174	0	107	1280
29	433	439	326	0	82	1280
30	365	701	136	0	78	1280
31	418	575	236	0	51	1280
32	383	472	364	0	61	1280
33	302	575	338	0	65	1280
34	482	631	99	0	68	1280
35	334	503	66	300	77	1280
36	342	621	242	0	75	1280
37	477	590	87	17	109	1280
38	232	545	399	0	104	1280
39	1572	1853	1428	0	267	5120
TOTAL	38,663	50,691	36,281	8905	8820	143,360
% of Total Average	28	35	25	6	6	100

Planimetric Densitometer Percentages
(corrected to 100%)
from 1972 Strip Map
Oconto River Watershed
Oconto, Wisconsin

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other
1	0.5	4.1	39.4	1.9	54.1
2	7.7	8.4	37.3	38.3	8.3
3	26.4	36.9	26.4	6.3	4.0
4	38.5	31.5	29.3	-	0.7
5	27.0	44.7	26.0	-	2.3
6	10.9	30.4	41.1	2.9	14.7
7	1.5	1.5	87.6	-	9.4
8	17.4	14.4	53.2	12.9	2.1
9	27.7	37.5	24.7	2.3	7.8
10	23.4	34.0	35.6	-	7.0
11	21.5	44.2	29.9	-	4.4
12	24.0	31.9	27.8	13.0	3.3
13	23.5	48.5	19.7	-	8.3
14	25.1	35.8	34.3	-	4.8
15	14.5	28.4	48.6	-	8.5
16	14.3	36.2	39.6	-	9.9
17	18.0	27.7	51.4	-	2.9
18	12.0	33.9	46.2	-	7.9
19	10.3	39.5	38.6	11.0	0.6
20	22.0	23.5	47.1	-	7.4

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other
21	14.4	16.1	63.9	-	5.6
22	8.7	31.9	55.1	-	4.3
23	7.3	13.3	70.8	-	8.6
24	1.1	5.4	85.6	-	7.9
25	6.1	24.1	65.0	-	4.8
26	2.2	11.6	79.6	2.1	4.5
27	0.6	8.3	88.7	-	2.4
28	1.6	5.7	87.4	-	5.3
29	-	-	98.2	-	1.8
30	-	1.0	91.7	-	7.3
31	-	13.8	70.6	4.5	11.1
32	10.6	18.5	66.8	-	4.1
33	1.3	2.4	91.3	-	5.0
34	19.5	53.5	18.9	-	8.1
35	26.9	55.7	13.2	-	4.2
36	12.4	39.5	44.9	-	3.2
37	25.2	53.8	16.3	-	4.7
38	31.3	42.3	23.7	-	2.7
39	23.3	44.6	29.4	-	2.7
40	37.3	32.0	24.7	-	6.0
41	35.2	36.6	25.6	-	2.6
42	32.8	58.7	4.6	-	3.9

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other
43	32.9	43.1	18.7	-	5.3
44	-	5.7	79.1	-	15.2
45	-	-	94.2	-	5.8
46	-	-	95.6	-	4.4
47	-	-	97.7	-	2.3
48	-	-	96.9	-	3.1
49	-	-	95.8	-	4.2
50	-	-	84.7	-	15.3
51	1.8	-	85.5	-	12.7
52	-	8.8	82.6	-	8.6
53	-	-	96.9	-	3.1
54	-	-	96.9	-	3.1
55	-	-	97.1	-	2.9

Acres per Land Use from Planimetric
Densitometer Percentages of 1972 Strip Map
Oconto River Watershed
Oconto, Wisconsin

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other	Total Acres.
1	26	210	2017	97	2770	5120
2	394	430	1910	1961	425	5120
3	1352	1889	1352	322	205	5120
4	1971	1613	1500	-	36	5120
5	1382	2289	1331	-	118	5120
6	558	1557	2104	148	753	5120
7	77	77	4485	-	481	5120
8	891	737	2724	660	108	5120
9	1418	1920	1265	118	399	5120
10	1198	1741	1823	-	358	5120
11	1101	2263	1531	-	225	5120
12	1229	1633	1423	666	169	5120
13	1203	2483	1009	-	425	5120
14	1285	1833	1756	-	246	5120
15	742	1454	2489	-	435	5120
16	732	1854	2027	-	507	5120
17	922	1418	2632	-	148	5120
18	614	1736	2365	-	405	5120
19	528	2022	1976	563	31	5120
20	1126	1203	2412	-	379	5120

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other	Total Acres
21	737	824	3272	-	287	5120
22	446	1633	2821	-	220	5120
23	374	681	3625	-	440	5120
24	56	276	4383	-	405	5120
25	312	1234	3328	-	246	5120
26	113	594	4075	108	230	5120
27	31	425	4541	-	123	5120
28	82	292	4475	-	271	5120
29	-	-	5028	-	92	5120
30	-	51	4695	-	374	5120
31	-	707	3615	230	568	5120
32	543	947	3420	-	210	5120
33	67	123	4674	-	256	5120
34	998	2739	968	-	415	5120
35	1377	2852	676	-	215	5120
36	635	2022	2299	-	164	5120
37	1290	2755	835	-	240	5120
38	1603	2166	1213	-	138	5120
39	1193	2284	1505	-	138	5120
40	477	410	316	-	77	1280
41	451	468	328	-	33	1280
42	420	751	59	-	50	1280
43	421	552	239	-	68	1280

Sample No.	Open Agriculture (02-01-02)	Closed Agriculture (02-01-01)	Forest (04)	Urban (01)	Other	Total Acres in Sample Box
44	-	73	1013	-	194	1280
45	-	-	1206	-	74	1280
46	-	-	1224	-	56	1280
47	-	-	1251	-	29	1280
48	-	-	1240	-	40	1280
49	-	-	1226	-	54	1280
50	-	-	1084	-	196	1280
51	23	-	1094	-	163	1280
52	-	113	1057	-	110	1280
53	-	-	1240	-	40	1280
54	-	-	1240	-	40	1280
55	-	-	1243	-	37	1280
TOTAL	55,334	30,398	114,639	4873	14,916	220,160

Planimetric Densitometer Readings
of Randomly Selected Sections for
Manitowoc River Watershed
Manitowoc, Wisconsin

Sample No.	Open Agric (02-01-02)	Closed Agric. (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
1	47.5	52.5	1.9	-	-	-	1.0	-	102.9	+2.9
2	10.0	8.0	1.6	-	-	-	-	-	96.7	B77.1 -3.3
3	32.9	34.4	2.7	24.4	-	-	0.5	-	94.9	-5.1
4	37.4	41.5	6.3	4.6	-	-	1.9	-	91.7	-8.3
5	47.2	44.4	-	-	-	2.4	2.9	-	96.9	-3.1
6	56.0	33.6	1.6	-	-	-	4.7	-	95.9	-4.1
7	31.1	41.5	16.2	-	-	-	2.4	-	91.8	-8.2
8	36.2	35.3	19.3	2.8	-	4.7	-	-	98.3	-1.7
9	33.1	53.4	13.1	-	-	-	1.8	-	101.4	+1.4
10	17.7	51.1	14.0	5.4	-	5.6	2.3	-	96.1	-3.9
11	-	-	92.4	5.0	-	-	-	-	97.4	-2.6
12	-	2.2	-	-	-	-	-	-	92.7	B90.5 -7.3
13	34.0	43.2	35.0	-	-	-	1.9	-	114.1	+14.1
14	38.5	43.1	7.3	-	-	-	4.2	-	93.1	-6.9
15	36.0	47.0	12.4	-	-	-	1.4	-	96.8	-3.2
16	27.3	18.9	20.4	-	-	-	0.4	31.6	98.6	-1.4
17	17.4	13.2	3.1	-	-	-	-	-	100.5	B66.8 +0.5
18	31.0	19.5	51.7	-	-	-	-	-	102.2	+2.2
19	38.4	46.1	14.4	-	-	-	-	-	98.9	[illegible] 1
20	39.0	52.1	5.4	-	-	-	4.7	-	101.2	+1.2

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
21	42.1	27.8	28.1	-	-	4.5	0.8	-	103.3	+3.3
22	17.0	57.7	11.9	4.5	-	-	-	-	91.1	-8.9
23	26.6	31.5	44.7	-	-	-	1.0	-	103.8	+3.8
24	36.2	33.7	9.0	10.9	-	-	4.9	-	94.7	-5.3
25	33.0	28.7	34.6	-	-	-	2.1	-	98.4	-1.6
26	23.9	15.4	2.8	-	-	-	-	-	101.8	B59.7 +1.8
27	42.2	51.1	6.8	-	-	-	-	5.3	105.4	+5.4
28	5.7	15.4	74.8	-	-	-	4.2	-	100.1	+0.1
29	42.4	25.8	30.4	-	-	-	0.2	-	98.8	-1.2
30	52.3	34.0	21.8	-	-	-	-	-	108.1	+8.1
31	31.0	37.5	28.3	-	-	4.1	-	-	100.9	+0.9
32	51.9	42.4	8.3	-	-	-	3.4	-	106.0	+6.0
33	51.9	27.2	12.2	-	-	-	-	-	91.3	-8.7
34	56.0	35.5	3.9	-	-	-	6.8	-	102.2	+2.2
35	30.8	44.0	17.0	-	-	-	-	-	91.8	-8.2
36	43.6	26.7	21.6	-	-	-	6.0	-	97.9	-2.1
37	41.7	46.6	11.6	-	-	-	3.7	-	103.6	+3.6
38	43.0	40.2	16.4	-	-	1.9	1.1	-	102.6	+2.6
39	38.0	51.5	8.6	-	-	1.5	1.1	-	100.7	+0.7
40	21.1	58.2	3.4	3.0	11.0	-	3.0	-	99.7	-0.3
41	24.6	45.5	4.1	19.3	-	-	-	-	93.5	-6.5

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
42	27.5	12.2	-	27.1	35.8	-	3.6	-	106.2	+6.2
43	27.4	28.0	3.8	-	33.6	0.9	-	-	93.7	-6.3
44	43.3	43.5	2.7	-	-	-	5.8	-	95.3	-4.7
45	50.5	34.1	3.6	-	-	-	4.5	-	92.7	-7.3
46	49.7	47.3	2.7	-	-	-	0.5	-	100.2	+0.2
47	41.4	35.3	15.1	-	-	3.9	-	-	95.7	-4.3
48	31.2	37.9	22.7	-	-	-	5.5	-	97.3	-2.7
49	51.3	42.5	4.4	-	-	-	3.4	-	101.6	+1.6
50	30.0	49.3	4.8	-	-	-	10.6	-	94.7	-5.3
51	38.3	52.3	5.6	-	-	-	5.2	-	101.4	+1.4
52	27.9	20.1	29.2	14.3	-	-	0.1	-	91.6	-8.4
53	55.7	31.4	6.3	5.1	-	-	0.4	-	98.9	-1.1
54	4.5	13.6	5.4	-	-	-	3.3	-	100.0	B73.2 -
55	20.8	72.5	5.9	-	-	-	2.0	-	101.2	+1.2
56	25.8	64.6	4.8	-	-	-	1.6	-	96.8	-3.2
57	39.3	32.7	7.4	2.8	-	12.5	2.5	-	97.2	-2.8
58	40.7	38.9	19.1	-	-	-	0.2	-	98.9	-1.1
59	41.3	55.6	3.9	-	-	-	1.0	-	101.8	+1.8
60	36.2	36.0	19.0	-	-	-	2.9	-	94.1	-5.9
61	48.9	41.1	14.9	-	-	-	0.8	-	105.7	+5.7
62	58.1	42.7	0.9	-	-	-	0.5	-	102.2	+2.2

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
63	32.7	39.4	8.8	7.0	-	1.9	3.7	-	93.5	-6.5
64	9.9	10.1	63.0	7.9	-	-	2.5	-	93.4	-6.6
65	47.4	48.2	-	-	-	.4	-	-	96.0	-4.0
66	33.3	43.5	8.7	-	-	7.8	1.2	-	94.5	-5.5
67	24.0	70.3	9.1	-	-	-	2.5	-	105.9	+5.9
68	42.6	42.5	-	1.9	-	-	3.0	-	90.0	-10.0
69	47.4	42.2	7.5	-	-	2.7	-	-	99.8	-0.2
70	56.0	47.7	0.5	-	-	4.6	-	-	108.8	+8.8
71	37.7	45.3	24.8	-	-	-	0.8	-	108.6	+8.6
72	40.8	48.7	16.6	-	-	3.3	-	-	109.4	+9.4
73	40.1	47.6	6.4	-	8.3	3.1	-	-	105.5	+5.5
74	50.1	43.9	-	-	-	-	0.9	-	94.9	-5.1
75	41.4	41.0	6.9	-	-	-	0.7	-	90.0	-10.0
76	49.4	39.3	-	3.2	-	-	2.4	-	94.3	-5.7
77	54.1	37.8	-	-	-	-	5.2	-	97.1	-2.9
78	45.1	43.2	2.0	0.9	-	-	4.3	-	95.5	-4.5
79	15.2	11.8	4.9	59.5	-	-	-	-	91.4	-9.6
80	38.4	28.6	19.0	-	-	8.6	1.7	-	96.3	-3.7
81	35.0	11.7	6.0	2.1	20.6	10.5	7.3	-	93.2	-6.8
82	27.9	59.7	5.6	-	-	-	1.9	-	95.1	-4.9
83	30.8	60.4	8.2	-	-	-	2.6	-	102.0	+2.0
84	27.2	63.8	1.5	-	-	-	4.6	-	97.1	-2.9

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
85	50.4	44.2	1.6	-	-	-	3.1	-	99.3	-0.7
86	42.9	43.4	7.7	-	-	-	0.6	-	94.6	-5.4
87	34.1	55.1	-	-	-	-	7.4	-	96.6	-3.4
88	33.9	23.9	-	29.2	-	20.2	-	-	107.2	+7.2
89	-	-	-	-	92.0	2.9	-	-	94.9	-5.1
90	27.8	54.8	1.0	-	6.6	-	1.8	-	92.0	-8.0
91	25.9	30.1	8.2	23.5	-	5.8	1.0	-	94.5	-5.5
92	3.6	4.3	35.1	51.7	-	12.0	-	-	109.7	+9.7
93	36.9	15.5	16.7	17.3	-	7.6	0.4	-	94.4	-5.6
94	41.7	44.0	-	-	-	9.4	6.5	-	101.6	+1.6
95	26.8	41.4	22.0	-	1.6	-	4.6	-	96.4	-3.6
96	16.1	49.3	33.7	-	-	-	0.5	-	99.6	-0.4
97	24.1	40.0	29.2	-	-	-	4.3	-	97.6	-2.4
98	45.3	24.5	27.9	-	-	-	4.7	-	102.4	+2.4
99	31.4	17.2	33.0	9.4	-	-	-	-	91.0	-9.0
100	33.1	14.8	41.0	-	-	-	2.7	-	91.6	-8.4
101	0.7	6.8	62.2	27.3	-	-	-	-	97.0	-3.0
102	31.6	43.6	15.5	-	7.7	-	5.7	-	104.1	+4.1
103	17.7	37.9	11.6	6.2	-	-	3.1	-	100.0	B23.5
104	26.1	40.3	32.8	-	-	-	2.4	-	108.3	+8.3
106	44.5	26.1	12.9	-	-	5.5	3.7	-	92.7	-7.3

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
106	39.2	34.6	10.6	-	-	9.1	5.6	-	99.1	-0.9
107	36.6	58.7	3.5	-	-	-	2.6	-	101.4	+1.4
108	33.7	53.5	5.1	-	-	-	0.4	-	92.7	-7.3
109	40.3	37.8	9.0	-	-	-	4.4	-	91.5	-8.5
110	22.1	32.0	27.5	-	-	11.9	8.2	-	101.7	+1.7
111	14.6	12.2	29.9	33.0	-	6.7	-	-	96.4	-3.6
112	37.9	44.8	10.3	-	-	-	0.7	-	92.8	-7.2
113	14.8	6.4	78.5	-	-	-	2.9	-	102.6	+2.6
114	16.2	57.0	17.3	1.6	-	-	-	-	92.1	-7.9
115	34.3	35.4	12.9	7.1	-	5.4	0.8	-	95.9	-4.1
116	51.6	52.3	-	-	-	-	-	-	103.9	+3.9
117	26.4	12.4	54.2	-	-	-	-	-	93.0	-7.0
118	46.5	54.2	3.3	-	-	-	3.7	-	107.7	+7.7
119	23.7	31.1	37.2	-	-	-	5.2	-	97.2	-2.8
120	6.6	4.3	84.2	-	-	-	0.5	-	95.6	-4.4
121	24.1	14.9	61.0	-	-	0.1	-	-	100.1	+0.1
122	17.4	33.3	56.5	-	-	-	-	-	107.2	+7.2
123	16.8	37.0	32.5	-	8.0	3.4	4.6	-	102.3	+2.3
124	15.1	30.7	52.8	-	-	1.9	2.0	-	102.5	+2.5
125	12.3	56.1	23.6	2.8	-	-	-	-	94.8	-5.2
126	40.3	36.1	22.2	-	-	-	1.8	-	100.4	+0.4

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
127	28.6	27.9	37.9	-	-	-	5.8	-	100.2	+0.2
128	21.0	54.8	26.2	-	-	1.5	1.5	-	105.0	+5.0
129	10.7	43.2	32.3	-	-	9.7	5.1	-	101.0	+1.0
130	26.6	60.9	5.8	-	-	-	3.5	-	96.8	-3.2
131	44.7	40.7	12.9	-	-	-	2.8	-	101.1	+1.1
132	17.0	14.9	23.6	41.2	-	3.4	0.7	-	100.8	+0.8
133	58.0	29.5	1.0	-	-	-	2.4	-	90.9	-9.1
134	29.0	16.3	0.7	9.1	37.3	-	0.3	-	92.7	-7.3
135	44.5	40.9	10.6	-	-	-	-	-	96.0	-4.0
136	15.9	42.3	14.2	30.7	-	-	-	-	103.1	+3.1
137	56.2	28.1	13.9	-	-	-	0.5	-	98.7	-1.3
138	26.4	30.5	25.5	18.2	-	-	1.3	-	101.9	+1.9
139	42.5	64.6	-	-	-	-	1.0	-	108.1	+8.1
140	38.7	38.7	15.0	3.1	-	-	-	-	95.5	-4.5
141	28.9	28.5	32.3	6.2	-	-	1.6	-	97.5	-2.5
142	58.5	38.5	1.0	-	-	-	-	-	98.0	-2.0
143	23.8	43.5	10.1	13.5	-	-	-	-	90.9	-9.1
144	53.4	37.3	13.2	-	-	-	-	-	103.9	+3.9
145	15.8	25.6	1.7	1.1	-	-	0.8	-	99.7	B54.7 -0.3
146	53.9	39.8	-	-	-	1.7	1.8	-	97.2	-2.8
147	30.8	47.9	5.2	-	2.8	-	3.3	-	90.0	-10.0
148	30.0	57.3	2.2	-	-	-	2.5	-	92.0	-8.0
149	23.4	17.1	-	-	-	-	-	-	100.0	B59.5 -

Acres per Land Use Category
of Randomly Selected Sections for
Manitowoc River Watershed
~~Manitowoc, Wisconsin~~

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
1	295	326	12	--	--	--	7	0	0
2	85	53	10	--	--	--	--	--	492
3	221	231	18	164	--	--	6	--	--
4	259	288	44	29	--	--	20	--	--
5	311	293	--	--	--	16	20	--	--
6	373	224	11	--	--	--	32	--	--
7	215	287	116	--	--	--	22	--	--
8	236	230	126	18	--	30	--	--	--
9	209	337	83	--	--	--	11	--	--
10	118	340	93	36	--	37	16	--	--
11	--	--	607	33	--	--	--	--	--
12	--	16	--	--	--	--	--	--	624
13	187	237	192	--	--	--	24	--	--
14	263	295	50	--	--	--	32	--	--
15	238	310	82	--	--	--	10	--	--
16	177	122	132	--	--	--	4	205	--
17	111	84	20	--	--	--	--	--	425
18	194	122	324	--	--	--	--	--	--
19	248	298	94	--	--	--	--	--	--
20	247	329	34	--	--	--	30	--	--
21	261	172	174	--	--	28	5	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
22	120	405	83	32	--	--	--	--	--
23	164	194	275	--	--	--	7	--	--
24	244	227	61	73	--	--	35	--	--
25	215	187	225	--	--	--	13	--	--
26	150	97	18	--	--	--	--	--	375
27	256	311	41	--	--	--	--	32	--
28	36	98	478	--	--	--	28	--	--
29	275	167	197	--	--	--	1	--	--
30	310	201	129	--	--	--	--	--	--
31	197	238	179	--	--	26	--	--	--
32	312	255	50	--	--	--	23	--	--
33	364	190	86	--	--	--	--	--	--
34	351	222	24	--	--	--	43	--	--
35	214	307	119	--	--	--	--	--	--
36	285	174	141	--	--	--	40	--	--
37	257	288	72	--	--	--	23	--	--
38	268	251	102	--	--	12	7	--	--
39	242	327	55	--	--	10	6	--	--
40	135	374	22	19	71	--	19	--	--
41	168	310	29	133	--	--	--	--	--
42	165	73	--	162	214	--	26	--	--
43	187	190	27	--	229	7	--	--	--
44	290	291	18	--	--	--	41	--	--
45	347	218	25	--	--	--	50	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-02)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
46	318	303	17	--	--	--	2	--	--
47	277	236	101	--	--	26	--	--	--
48	205	249	149	--	--	--	37	--	--
49	323	268	28	--	--	--	21	--	--
50	202	332	32	--	--	--	74	--	--
51	242	330	35	--	--	--	33	--	--
52	194	139	203	99	--	--	5	--	--
53	360	203	41	33	--	--	3	--	--
54	29	87	35	--	--	--	20	--	469
55	132	458	37	--	--	--	13	--	--
56	170	427	32	--	--	--	11	--	--
57	259	215	49	18	--	82	17	--	--
58	263	252	124	--	--	--	1	--	--
59	260	349	24	--	--	--	7	--	--
60	245	230	122	--	--	--	43	--	--
61	295	248	90	--	--	--	7	--	--
62	364	267	6	--	--	--	3	--	--
63	223	269	60	48	--	--	40	--	--
64	68	69	430	54	--	--	19	--	--
65	315	321	--	--	--	4	--	--	--
66	223	294	59	--	--	53	11	--	--
67	144	423	55	--	--	--	18	--	--
68	300	299	11	--	--	--	30	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-02)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
69	304	271	48	--	--	17	--	--	--
70	329	279	4	--	--	28	--	--	--
71	220	265	145	--	--	--	10	--	--
72	239	284	97	--	--	20	--	--	--
73	242	288	40	--	50	20	--	--	--
74	337	295	--	--	--	--	8	--	--
75	291	287	48	--	--	--	14	--	--
76	334	266	--	22	--	--	18	--	--
77	356	249	--	--	--	--	35	--	--
78	302	289	13	6	--	--	30	--	--
79	107	82	34	417	--	--	--	--	--
80	255	190	126	--	--	57	12	--	--
81	239	80	41	13	141	72	54	--	--
82	187	401	38	--	--	--	14	--	--
83	193	379	51	--	--	--	17	--	--
84	179	420	10	--	--	--	31	--	--
85	322	285	10	--	--	--	23	--	--
86	289	293	52	--	--	--	6	--	--
87	226	365	--	--	--	--	49	--	--
88	202	143	--	174	--	121	--	--	--
89	--	--	--	--	619	21	--	--	--
90	192	379	7	--	46	--	16	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-02)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
91	175	203	55	159	--	39	9	--	--
92	24	28	209	306	--	73	-	--	--
93	249	105	113	117	--	51	5	--	--
94	263	277	--	--	--	59	41	--	--
95	178	274	146	--	11	--	31	--	--
96	103	317	216	--	--	--	4	--	--
97	158	262	191	--	--	--	29	--	--
98	283	153	174	--	--	--	30	--	--
99	220	121	232	67	--	--	--	--	--
100	230	103	284	--	--	--	23	--	--
101	5	45	410	180	--	--	--	--	--
102	194	268	95	--	47	--	36	--	--
103	113	242	74	40	--	--	21	--	150
104	153	236	192	--	--	--	59	--	--
105	306	179	89	--	--	38	28	--	--
106	253	223	68	--	--	59	37	--	--
107	231	370	22	--	--	--	17	--	--
108	231	367	35	--	--	--	7	--	--
109	280	262	63	--	--	--	35	--	--
110	139	202	173	--	--	75	51	--	--
111	97	81	198	219	--	45	--	--	--
112	260	307	70	--	--	--	3	--	--
113	92	40	490	--	--	--	18	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-02)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
114	113	395	121	11	--	--	--	--	--
115	228	236	86	47	--	36	7	--	--
116	318	322	--	--	--	--	--	--	--
117	181	86	373	--	--	--	--	--	--
118	274	320	20	--	--	--	26	--	--
119	156	205	244	--	--	--	35	--	--
120	44	29	562	--	--	--	5	--	--
121	154	95	390	--	--	1	--	--	--
122	104	199	337	--	--	--	--	--	--
123	104	232	204	--	50	21	29	--	--
124	94	191	317	--	--	5	33	--	--
125	83	379	160	18	--	--	--	--	--
126	257	230	141	--	--	--	12	--	--
127	182	178	242	--	--	--	38	--	--
128	128	333	159	--	--	9	11	--	--
129	60	274	205	--	--	61	40	--	--
130	176	402	38	--	--	--	24	--	--
131	283	254	82	--	--	--	21	--	--
132	108	95	150	262	--	22	3	--	--
133	405	206	7	--	--	--	22	--	--
134	200	112	5	63	256	--	4	--	--
135	298	272	70	--	--	--	--	--	--
136	98	263	88	191	--	--	--	--	--

Sample No.	Agriculture Open (02-01-02)	Agriculture Closed (02-01-02)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
137	364	182	90	--	--	--	4	--	--
138	166	191	160	114	--	--	9	--	--
139	250	380	--	--	--	--	10	--	--
140	259	259	101	21	--	--	--	--	--
141	189	187	212	41	--	--	11	--	--
142	382	252	6	--	--	--	--	--	--
143	167	307	71	95	--	--	--	--	--
144	329	230	81	--	--	--	--	--	--
145	101	164	11	7	--	--	6	--	351
146	355	262	--	--	--	11	12	--	--
147	217	337	36	--	20	--	30	--	--
148	207	396	15	--	--	--	22	--	--
149	150	109	--	--	--	--	--	--	381
Total	31977	35476	15565	3541	1754	1292	2251	237	3267
Percentage of total watershed (92093 acres)	35	39	17	4	2	1	2	0	

Planimetric Densitometer Readings
of Randomly Selected Sections for
Oconoto River Watershed
Oconto, Wisconsin

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
1-7			NO IMAGERY							
8	-	-	85.3	3.8	-	0.1	6.5	-	95.7	-4.3
9			NO IMAGERY							
10	-	-	95.7	3.9	-	0.3	-	-	99.9	-0.1
11	7.5	41.0	44.2	2.9	-	-	1.2	-	96.8	-3.2
12	-	0.5	84.6	9.3	-	-	3.8	-	98.2	-1.8
13	3.3	-	84.2	7.3	-	2.6	-	-	97.4	-2.6
14	-	-	91.8	0.6	-	4.8	1.6	-	98.8	-1.2
15	-	-	75.7	26.9	-	-	-	-	102.6	+2.6
16	-	-	83.1	11.2	-	-	3.7	-	98.0	-2.0
17	-	-	95.2	-	-	-	-	-	95.2	-4.8
18	-	-	94.0	2.0	-	-	-	-	96.0	-4.0
19	-	-	97.8	-	-	-	-	-	97.8	-2.2
20	-	-	95.1	3.3	-	-	0.8	-	99.2	-0.8
21	-	-	97.0	-	-	-	4.6	-	101.6	+1.6
22	-	-	85.9	17.2	-	-	2.9	-	106.0	+6.0
23	-	9.3	87.7	5.0	-	-	3.5	-	105.5	+5.5
24	-	1.9	87.4	1.7	-	5.6	8.4	-	105.0	+5.0
25	-	18.6	78.8	4.4	-	3.2	3.0	-	108.0	+8.0
26	-	4.7	70.5	-	-	9.3	11.3	-	95.8	-4.2

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
27	-	-	57.9	17.1	-	12.0	13.2	-	100.8	+0.8
28	10.4	28.8	13.0	4.9	22.8	15.4	9.9	-	105.2	+5.2
29	-	23.3	73.5	1.1	-	3.0	5.9	-	106.7	+6.7
30	-	-	78.2	6.6	-	10.3	10.0	-	105.1	+5.1
31	-	0.8	76.0	-	-	-	-	-	104.2	B27.4 +4.2
32	-	-	98.4	-	-	0.1	-	-	98.5	-1.5
33	-	30.7	48.4	-	-	12.5	15.2	-	106.8	+6.8
34	-	6.6	83.1	3.5	-	5.3	10.1	-	108.6	+8.6
35	-	0.5	62.4	-	-	23.1	16.2	-	102.2	+2.2
36	-	-	94.5	3.6	-	0.2	-	-	98.3	-1.7
37	-	-	83.1	0.7	-	12.1	-	-	95.9	-4.1
38	-	7.3	84.1	6.7	-	2.4	0.1	-	100.6	+0.6
39	-	6.7	59.0	1.4	10.0	12.2	16.0	-	105.3	+5.3
40	-	6.5	74.5	-	-	5.9	7.1	-	94.0	-6.0
41	-	-	86.5	5.2	-	1.9	5.8	-	99.4	-0.6
42	-	21.3	64.1	1.1	-	-	7.8	-	94.3	-5.7
43	-	0.3	88.1	2.9	-	0.5	9.6	-	101.4	+1.4
44	-	-	77.3	6.5	-	9.2	7.6	-	100.6	+0.6
45	-	-	41.4	2.2	-	45.7	10.7	-	100.0	-
46	-	0.7	41.1	4.7	-	36.2	12.8	-	95.5	-4.5
47	-	2.1	97.3	-	-	0.8	-	-	100.2	+0.2

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
48	-	1.0	89.7	-	-	1.0	8.2	-	99.9	-0.1
49	-	7.7	78.1	0.6	-	7.6	6.3	-	100.3	+0.3
50	-	-	82.1	2.5	-	12.3	7.0	-	103.9	+3.9
51	-	-	82.0	2.1	-	15.2	0.6	-	99.9	-0.1
52	-	5.1	87.0	-	-	8.3	5.9	-	106.3	+6.3
53	-	-	96.4	0.1	-	-	8.2	-	104.7	+4.7
54	-	4.5	80.3	3.5	-	6.1	11.9	-	106.3	+6.3
55	-	-	95.4	3.5	-	-	-	-	98.9	-1.1
56	-	0.5	87.8	1.6	-	6.8	6.5	-	103.2	+3.2
57	-	8.9	78.7	4.9	-	4.1	5.2	-	101.8	+1.8
58	-	6.6	83.9	1.6	-	-	12.1	-	104.2	+4.2
59	8.9	25.3	58.0	-	-	4.3	10.3	-	106.8	+6.8
60	-	-	97.5	-	-	-	2.9	-	100.4	+0.4
61	-	14.0	82.2	11.4	-	-	0.8	-	108.4	+8.4
62	13.2	-	65.9	9.5	-	-	6.5	-	95.1	-4.9
63	2.7	1.9	-	74.3	-	13.2	6.2	-	98.3	-1.7
64	-	1.2	91.5	3.1	-	4.4	6.2	-	106.4	+6.4
65	-	26.1	61.0	-	-	8.9	12.9	-	108.9	+8.9
66	0.3	13.4	81.2	-	-	2.4	8.2	-	105.5	+5.5
67	-	-	95.5	4.1	-	0.7	-	-	100.3	+0.3
68	-	-	96.3	0.7	-	-	4.6	-	101.6	-1.6
69	5.8	3.4	50.1	24.7	-	5.3	10.4	-	99.7	-0.3

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
48	-	1.0	89.7	-	-	1.0	8.2	-	99.9	-0.1
49	-	7.7	78.1	0.6	-	7.6	6.3	-	100.3	+0.3
50	-	-	82.1	2.5	-	12.3	7.0	-	103.9	+3.9
51	-	-	82.0	2.1	-	15.2	0.6	-	99.9	-0.1
52	-	5.1	87.0	-	-	8.3	5.9	-	106.3	+6.3
53	-	-	96.4	0.1	-		8.2	-	104.7	+4.7
54	-	4.5	80.3	3.5	-	6.1	11.9	-	106.3	+6.3
55	-	-	95.4	3.5	-	-	-	-	98.9	-1.1
56	-	0.5	87.8	1.6	-	6.8	6.5	-	103.2	+3.2
57	-	8.9	78.7	4.9	-	4.1	5.2	-	101.8	+1.8
58	-	6.6	83.9	1.6	-	-	12.1	-	104.2	+4.2
59	8.9	25.3	58.0	-	-	4.3	10.3	-	106.8	+6.8
60	-	-	97.5	-	-		2.9	-	100.4	+0.4
61	-	14.0	82.2	11.4	-	-	0.8	-	108.4	+8.4
62	13.2	-	65.9	9.5	-	-	6.5	-	95.1	-4.9
63	2.7	1.9	-	74.3	-	13.2	6.2	-	98.3	-1.7
64	-	1.2	91.5	3.1	-	4.4	6.2	-	106.4	+6.4
65	-	26.1	61.0	-	-	8.9	12.9	-	108.9	+8.9
66	0.3	13.4	81.2	-	-	2.4	8.2	-	105.5	+5.5
67	-	-	95.5	4.1	-	0.7	-	-	100.3	+0.3
68	-	-	96.3	0.7	-	-	4.6	-	101.6	-1.6
69	5.8	3.4	50.1	24.7	-	5.3	10.4	-	99.7	-0.3

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
										B
70	6.1	10.5	45.0	10.6	-	-	1.3	-	100.0	-26.5
71	-	24.9	41.6	23.1	-	-	0.5	-	90.1	-9.9
72	-	4.6	94.1	2.6	-	-	0.5	-	101.2	+1.8
73	-	-	85.0	11.0	-	2.7	7.0	-	105.7	+5.7
74	-	12.5	81.4	-	-	3.3	11.3	-	108.5	+8.5
75	-	-	87.1	4.5	-	2.4	9.5	-	103.5	+3.5
76	-	21.3	44.1	26.2	-	-	14.6	-	106.2	+6.2
77	-	29.7	27.6	23.9	-	-	13.6	-	94.8	-5.2
78	2.5	21.2	50.2	19.1	-	-	8.1	-	101.1	+1.1
79	3.8	13.3	83.0	-	-	-	6.0	-	106.1	+6.1
80	1.1	-	98.2	-	-	2.7	1.9	-	103.9	+3.9
81	4.0	38.3	50.2	-	-	-	13.4	-	105.9	+5.9
82	-	6.8	89.9	-	-	-	8.0	-	104.7	+4.7
83	6.4	-	64.2	18.3	-	-	8.8	-	97.7	-2.3
84	3.3	75.9	-	13.1	-	-	-	-	92.3	-7.7
85	-	13.7	29.6	48.1	-	0.7	6.9	-	99.0	-1.0
86	-	-	11.2	90.1	-	2.5	-	-	103.8	+3.8
87	12.1	7.8	80.4	-	-	-	2.1	-	102.4	+2.4
88	13.9	82.3	-	1.1	-	1.6	6.9	-	105.8	+5.8
89	1.0	-	36.3	61.8	-	2.1	-	-	101.2	+1.2
90	2.2	2.7	57.1	10.1	-	16.0	9.0	-	97.1	-2.9

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
91	-	-	95.0	4.4	-	-	-	-	99.4	-0.6
92	35.1	-	45.7	21.8	-	-	6.4	-	109.0	+9.0
93	3.3	0.7	92.9	4.4	-	-	-	-	101.3	+1.3
94	-	7.7	30.7	57.2	-	0.8	5.1	-	101.5	+1.5
95	-	-	95.1	7.9	-	-	1.1	-	104.1	+4.1
96	0.4	-	95.8	2.2	-	-	3.8	-	102.2	+2.2
97	-	8.7	83.0	-	-	4.0	8.2	-	103.9	+3.9
98	-	21.6	21.2	43.6	-	0.7	7.1	-	94.2	-5.8
99	3.6	-	31.4	58.2	-	-	1.9	-	95.1	-4.9
100	0.8	6.9	46.1	43.2	-	-	3.3	-	100.3	+0.3
101	0.4	-	10.2	81.3	-	-	-	-	91.9	-8.1
102	-	-	79.8	21.3	-	3.6	-	-	104.7	+4.7
103	-	-	88.5	0.8	-	7.6	10.9	-	107.8	+7.8
104	-	2.0	44.2	59.2	-	-	1.0	-	106.4	+6.4
105	-	11.0	-	86.4	-	-	-	-	97.4	-2.6
106	7.2	-	90.6	0.4	-	-	5.6	-	103.8	+3.8
107	-	-	93.0	4.7	-	1.3	1.3	-	100.3	+0.3
108	-	4.1	91.6	2.9	-	-	3.9	-	102.5	+2.5
109	-	-	51.6	-	-	48.2	5.2	-	105.0	+5.0
110	-	-	97.9	-	-	0.4	-	-	98.3	-1.7
111	-	-	90.0	10.9	-	-	-	-	100.9	+0.9

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
112	-	-	92.5	4.8	-	1.9	-	-	99.2	-0.8
113	2.5	-	71.2	26.1	-	-	3.7	-	103.5	+3.5
114	1.9	25.1	74.3	-	-	-	-	-	101.3	+1.3
115	19.6	25.1	56.1	7.1	-	-	1.7	-	109.6	+9.6
116	3.0	31.2	60.4	6.5	-	0.1	3.0	-	101.2	+1.2
117	-	5.7	60.0	38.9	-	-	-	-	104.6	+4.6
118	-	18.2	43.0	38.6	-	-	3.6	-	103.4	+3.4
119	-	-	95.2	-	-	3.6	-	-	98.8	-1.2
120	0.5	-	98.6	-	-	-	-	-	99.1	-0.9
121	-	21.0	72.6	-	-	2.5	5.9	-	102.0	+2.0
122	27.6	18.9	46.2	-	-	-	12.2	-	104.9	+4.9
123	-	45.8	45.2	2.8	-	1.9	4.0	-	99.7	-0.3
124	-	2.9	70.0	22.2	-	-	5.8	-	100.9	+0.9
125A	-	6.8	82.0	2.8	-	0.4	1.9	-	93.9	-6.1
125B	-	27.8	58.1	10.9	-	-	0.9	-	97.7	-2.3
126	-	0.3	97.3	-	-	1.4	-	-	99.0	-1.0
127	5.1	2.9	84.5	3.0	-	3.0	5.9	-	104.4	+4.4
128	-	56.5	25.8	5.6	-	-	4.2	-	92.1	-7.9
129	-	25.7	62.0	6.2	-	-	-	-	93.9	-6.1
130	6.5	45.6	27.5	-	-	12.2	-	-	91.8	-8.2
131	-	-	94.8	4.1	-	-	0.8	-	99.7	-0.3

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
132	-	-	95.0	2.2	-	0.8	4.3	-	102.3	+2.3
133	-	9.3	84.0	-	-	3.4	7.8	-	104.5	+4.5
134	11.7	31.2	46.4	-	-	1.7	5.6	-	96.6	-3.4
135	4.2	54.3	39.4	3.4	-	4.8	-	-	106.1	+6.1
136	10.0	33.0	36.4	8.4	-	2.6	-	-	90.4	-9.6
137	16.6	-	-	79.1	-	0.9	6.5	-	103.1	+3.1
138	1.9	16.4	54.1	22.3	-	3.9	-	-	98.6	-1.4
139	-	19.0	57.8	12.0	-	4.4	3.5	-	96.7	-3.3
140	-	14.8	41.5	-	-	19.8	5.5	-	100.0	B18.4
141	3.9	-	89.4	6.9	-	-	3.2	-	103.4	+3.4
142	-	6.5	72.8	13.5	-	11.3	-	-	104.1	+4.1
143	5.8	14.7	79.3	-	-	0.7	3.7	-	104.2	+4.2
144	16.8	42.7	31.8	-	-	6.6	-	-	97.9	-2.1
145	19.6	61.3	16.4	-	-	4.7	2.6	-	104.6	+4.6
146	19.5	5.9	62.3	8.0	-	5.9	3.1	-	104.7	+4.7
147	26.7	49.6	13.5	5.4	-	-	5.7	-	100.9	+0.9
148	12.1	27.0	52.0	-	-	5.8	-	-	97.8	-2.2
149	11.4	41.6	6.0	24.1	-	5.5	5.7	-	94.3	-5.7
150	-	-	92.5	5.9	-	2.4	-	-	100.8	+0.8
151	22.1	27.3	34.2	6.4	-	-	6.4	-	96.4	-3.6
152	28.9	15.8	8.8	51.3	-	-	-	-	104.8	+4.8

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
153	20.3	49.4	23.8	-	3.2	0.6	7.1	-	104.4	+4.4
154	20.4	36.4	8.9	29.4	-	-	5.7	-	100.8	+0.8
155	12.5	28.8	43.7	20.4	-	-	1.5	-	106.9	+6.9
156	16.4	39.7	38.0	-	-	-	6.1	-	100.2	+0.2
157	21.1	51.7	11.9	13.8	-	-	-	-	98.5	-1.5
158	35.3	47.3	10.6	-	-	-	3.2	-	96.4	-3.6
159	8.2	8.4	-	81.2	-	-	-	-	97.2	-2.8
160	12.2	39.2	-	49.7	-	-	-	-	101.1	+1.1
161	-	17.0	-	16.5	-	-	2.5	65.5	101.5	+1.5
162	17.0	17.3	-	19.6	-	-	1.9	54.0	109.8	+9.8
163	29.6	19.3	-	50.0	-	-	-	5.5	104.4	+4.4
164	30.6	5.9	55.3	-	-	-	-	-	91.8	-8.2
165	26.0	41.1	35.2	-	-	1.4	-	-	103.7	+3.7
166	27.7	22.5	53.0	-	-	-	-	-	103.2	+3.2
167	22.6	29.4	44.2	-	-	5.4	6.4	-	108.0	+8.0
168	58.6	41.3	-	3.9	-	-	-	-	103.8	+3.8
169	26.5	17.2	-	-	-	2.5	-	63.1	109.3	+9.3
170	17.6	48.7	30.6	-	-	-	1.6	-	98.5	-1.5
171	23.8	3.6	-	40.3	-	-	-	34.5	102.2	+2.2
172	-	3.4	69.1	36.3	-	-	-	-	108.8	+8.8
173	-	-	56.9	52.5	-	-	-	-	109.4	+9.4

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
174	28.6	36.9	29.0	2.4	-	-	-	-	96.9	-3.1
175	14.8	23.1	56.9	-	-	0.4	-	-	95.2	-4.8
176	14.3	54.7	36.6	-	-	-	0.2	-	105.8	+5.8
177	28.7	50.7	12.0	2.9	-	-	4.6	-	98.9	-1.1
178	14.6	33.5	42.8	-	-	-	3.2	-	94.1	-5.9
179	22.2	42.0	29.2	-	-	2.8	4.7	-	100.9	+0.9
180	25.0	53.4	26.0	-	-	-	-	-	104.4	+4.4
181	27.0	55.0	14.5	-	-	-	7.3	-	103.8	+3.8
182	-	-	35.2	74.3	-	-	-	-	109.5	+9.5
183	-	-	77.2	22.2	-	9.6	-	-	109.0	+9.0
184	23.8	22.7	31.1	-	-	-	-	-	97.6	-2.4
185	24.8	25.4	49.9	-	-	-	-	-	100.1	+0.1
186	8.0	2.7	50.6	21.2	-	10.8	-	-	93.3	-6.7
187	37.5	32.7	12.3	15.0	-	-	9.8	-	107.3	+7.3
188	31.5	28.2	14.4	-	-	5.7	11.0	-	90.8	-9.2
189	26.3	52.4	5.4	4.0	-	-	6.8	-	94.9	-5.1
190	19.8	39.2	24.1	-	-	-	7.2	-	90.3	-9.7
191	21.3	43.5	23.4	-	-	-	5.2	-	93.4	-6.6
192	-	-	94.8	6.3	-	0.3	-	-	101.4	+1.4
193	-	-	81.8	24.9	-	-	-	-	106.7	+6.7
194	16.1	14.4	58.3	-	-	10.7	-	-	99.5	-0.5

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
195	14.3	33.9	54.7	-	-	-	-	-	102.9	+2.9
196	12.2	57.6	35.0	-	-	-	-	-	104.8	+4.8
197	3.7	23.2	47.9	21.4	-	3.2	4.5	-	103.9	+3.9
198	15.8	39.8	33.8	-	-	5.6	-	-	95.0	-5.0
199	28.4	56.7	10.3	-	-	4.5	1.2	-	101.1	+1.1
200	31.6	30.5	-	20.5	-	6.2	2.1	-	90.9	-9.1
201	36.1	43.4	-	13.2	-	3.3	9.3	-	105.3	+5.3
202	13.1	47.5	32.9	-	-	-	0.5	-	94.0	-6.0
203	-	4.3	55.0	31.2	-	10.4	-	-	100.9	+0.9
204	15.7	23.8	45.3	11.0	-	2.2	-	-	98.0	-2.0
205	11.4	31.0	47.6	-	-	3.5	-	-	93.5	-6.5
206	15.0	28.0	14.4	30.0	-	3.4	3.0	-	93.8	-6.2
207	16.5	20.7	12.7	36.9	-	-	7.3	-	94.1	-5.9
208	12.2	10.1	-	24.9	-	-	-	57.9	105.1	+5.1
209	23.2	40.4	-	30.1	-	5.7	-	-	99.4	-0.6
210	-	13.8	-	18.3	-	-	-	-	100.0	B67.9
211	-	-	86.8	11.8	-	-	6.4	-	105.0	+5.0
212	-	-	28.4	76.2	-	-	-	-	104.6	+4.6
213	29.6	31.3	31.8	-	-	-	-	-	92.7	-7.3
214	11.0	49.9	-	23.6	-	2.8	6.1	-	93.4	-6.6
215	20.8	28.2	5.3	41.4	-	-	-	-	95.7	-4.3
216	7.0	15.6	-	66.9	-	-	6.4	-	95.9	-4.1

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
217	21.2	13.2	12.1	25.6	-	5.6	3.2	21.5	102.4	+2.4
218	-	-	24.2	-	43.5	40.0	-	-	107.7	+7.7
219	15.4	14.5	-	61.8	-	3.7	-	-	95.4	-4.6
220	19.0	56.6	17.0	-	-	-	-	-	92.6	-7.4
221	23.0	60.0	8.0	-	-	-	15.5	-	106.5	+6.5
222	8.8	-	10.4	83.8	-	-	-	-	103.0	+3.0
223	-	-	-	3.7	-	-	1.8	32.5	100.0	B62. -
224	-	3.6	93.0	-	-	-	-	-	96.6	-3.4
225	28.1	47.8	15.5	-	-	1.8	6.6	-	99.8	-0.2
226	18.7	8.6	10.8	22.4	12.5	12.9	10.8	-	96.7	-3.3
227	22.6	35.9	4.7	10.3	12.7	-	6.3	-	92.5	-7.5
228	2.9	20.2	39.3	25.1	-	-	8.9	-	96.4	-3.6
229	22.1	44.7	31.8	-	-	-	10.8	-	109.4	+9.4
230	6.2	7.8	-	8.5	-	-	1.6	79.2	103.3	+3.3
231	56.9	25.7	-	8.9	-	-	7.8	-	99.3	-0.7
232	9.1	-	-	-	84.2	5.9	-	-	99.2	-0.8
233	5.6	-	92.1	-	-	-	-	-	97.7	-2.3
234	18.6	26.6	39.6	-	-	-	7.7	-	92.5	-7.5
235	16.5	41.1	30.4	-	-	2.9	0.5	-	91.4	-8.6
236	25.8	47.4	-	20.3	-	-	-	-	93.5	-6.5
237	14.1	8.6	8.0	10.3	46.4	5.9	-	-	93.3	-6.7

Sample No.	Open Agric (02-01-02)	Closed Agric (02-01-02)	Forest (04)	Wetlands (06)	Urban (01)	Water (05)	Other	Clouds	Total	Error
238	-	10.0	71.9	2.4	-	-	6.6	-	90.9	-9.1
239	20.4	-	58.2	-	-	2.6	9.2	-	90.4	-9.6
240	40.5	12.8	-	2.9	-	9.3	-	36.1	101.6	+1.6
241	42.6	40.5	-	6.7	-	2.3	-	2.3	94.4	-5.6
242	46.9	12.2	-	26.5	-	7.8	-	-	93.4	-6.6
243	20.0	-	-	58.0	-	-	-	-	100.0	B22.0
244	5.5	-	76.8	-	-	5.5	7.0	-	94.8	-5.2
245	13.9	46.1	26.4	-	-	6.2	2.7	-	95.3	-4.7
246	21.2	51.1	20.8	-	-	-	1.0	-	94.1	-5.9
247	9.4	55.6	19.4	-	-	2.6	11.6	-	98.6	-1.4
248	20.3	62.8	7.2	-	-	-	4.4	-	94.7	-5.3
249	3.3	-	63.3	-	-	14.2	9.2	-	90.0	-10.0
250	8.6	42.8	33.9	-	-	-	7.1	-	92.4	-7.6
251	22.8	52.5	15.5	-	-	1.6	0.6	-	93.0	-7.0
252	10.0	37.3	40.4	-	-	-	5.5	-	94.1	-5.9

Acres per Land Use Category
of Randomly Selected Sections for
Oconto River Watershed
Oconto, Wisconsin

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--
8	--	--	570	26	--	--	44	--	--
9	--	--	--	--	--	--	--	--	--
10	--	--	614	26	--	--	--	--	--
11	50	271	292	19	--	--	8	--	--
12	--	3	551	61	--	--	25	--	--
13	22	--	553	48	--	17	--	--	--
14	--	--	595	4	--	31	10	--	--
15	--	--	472	168	--	--	--	--	--
16	--	--	543	73	--	--	24	--	--
17	--	--	640	--	--	--	--	--	--
18	--	--	627	13	--	--	--	--	--
19	--	--	640	--	--	--	--	--	--
20	--	--	614	21	--	--	5	--	--
21	--	--	611	--	--	--	29	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
22	--	--	517	104	--	--	19	--	--
23	--	57	532	30	--	--	21	--	--
24	--	13	531	11	--	34	51	--	--
25	--	110	465	27	--	20	18	--	--
26	--	31	471	--	--	62	76	--	--
27	--	--	368	109	--	80	83	--	--
28	63	175	79	30	138	93	62	--	--
29	--	139	439	6	--	18	38	--	--
30	--	--	475	40	--	63	62	--	--
31	--	5	467	--	--	--	--	--	168
32	--	--	639	--	--	1	--	--	--
33	--	184	289	--	--	73	94	--	--
34	--	40	487	21	--	32	60	--	--
35	--	3	391	--	--	145	101	--	--
36	--	--	615	24	--	1	--	--	--
37	--	--	554	5	--	81	--	--	--
38	--	46	535	43	--	15	1	--	--
39	--	41	358	9	61	74	97	--	--
40	--	45	506	--	--	40	49	--	--
41	--	--	557	34	--	12	37	--	--
42	--	145	434	8	--	--	53	--	--
43	--	2	556	18	--	3	61	--	--
44	--	--	492	41	--	59	48	--	--
45	--	--	265	14	--	293	68	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
46	--	5	275	31	--	243	86	--	--
47	--	13	622	--	--	5	--	--	--
48	--	6	575	--	--	6	53	--	--
49	--	49	498	4	--	49	40	--	--
50	--	--	505	15	--	76	44	--	--
51	--	--	525	13	--	97	5	--	--
52	--	31	522	--	--	50	37	--	--
53	--	--	588	1	--	--	51	--	--
54	--	27	481	21	36	71	4	--	--
55	--	--	618	22	--	--	--	--	--
56	--	3	544	10	--	42	41	--	--
57	--	56	495	31	--	26	32	--	--
58	--	40	515	10	--	--	75	--	--
59	53	151	346	--	--	26	64	--	--
60	--	--	621	--	--	--	19	--	--
61	--	82	482	72	--	--	4	--	--
62	88	--	442	64	--	--	46	--	--
63	17	13	--	484	--	86	40	--	--
64	--	7	548	18	--	26	41	--	--
65	--	152	356	--	--	52	80	--	--
66	2	81	491	--	--	15	51	--	--
67	--	--	609	26	--	5	--	--	--
68	--	--	607	4	--	--	29	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
69	37	22	319	157	--	34	71	--	--
70	39	67	288	68	--	--	8	--	170
71	--	175	292	162	--	--	11	--	--
72	--	29	591	17	--	--	3	--	--
73	--	--	512	66	--	16	46	--	--
74	--	73	477	--	--	19	71	--	--
75	--	--	538	28	--	15	59	--	--
76	--	128	265	157	--	--	90	--	--
77	--	200	186	161	--	--	93	--	--
78	16	134	317	121	--	--	52	--	--
79	23	80	498	--	--	--	39	--	--
80	7	--	604	--	--	17	12	--	--
81	25	231	302	--	--	--	82	--	--
82	--	42	548	--	--	--	50	--	--
83	42	--	420	120	--	--	58	--	--
84	25	524	--	91	--	--	--	--	--
85	--	89	191	311	--	5	44	--	--
86	--	--	69	556	--	15	--	--	--
87	76	49	502	--	--	--	13	--	--
88	84	496	--	7	--	10	43	--	--
89	6	--	230	392	--	12	--	--	--
90	15	18	376	65	--	105	61	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
91	--	--	612	28	--	--	--	--	--
92	204	--	266	127	--	--	43	--	--
93	21	4	587	28	--	--	--	--	--
94	--	49	194	361	--	5	31	--	--
95	--	--	584	49	--	--	7	--	--
96	3	--	600	14	--	--	23	--	--
97	--	54	511	--	--	25	50	--	--
98	--	146	144	295	--	5	50	--	--
99	24	--	211	391	--	--	14	--	--
100	5	44	294	276	--	--	21	--	--
101	3	--	72	565	--	--	--	--	--
102	--	--	488	130	--	22	--	--	--
103	--	--	522	5	--	45	68	--	--
104	--	12	265	355	--	--	--	--	--
105	--	73	--	567	--	--	--	--	--
106	44	--	558	3	--	--	35	--	--
107	--	--	593	30	--	8	9	--	--
108	--	26	572	18	--	--	24	--	--
109	--	--	314	--	--	293	33	--	--
110	--	--	637	--	--	3	--	--	--
111	--	--	571	69	--	--	--	--	--
112	--	--	597	31	--	12	--	--	--
113	15	--	440	161	--	--	24	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
114	12	159	469	--	--	--	--	--	--
115	113	145	325	41	--	--	16	--	--
116	19	197	382	41	--	1	--	--	--
117	--	35	367	238	--	--	--	--	--
118	--	113	266	239	--	--	22	--	--
119	--	--	617	--	--	23	--	--	--
120	3	--	637	--	--	--	--	--	--
121	--	132	455	--	--	16	37	--	--
122	168	115	281	--	--	--	76	--	--
123	--	294	290	18	--	12	26	--	--
124	--	18	444	141	--	--	37	--	--
125A	--	46	557	19	--	3	15	--	--
125B	--	182	380	71	--	--	7	--	--
126	--	2	629	--	--	9	--	--	--
127	31	18	517	18	--	18	38	--	--
128	--	390	178	39	--	--	33	--	--
129	--	175	421	42	--	--	2	--	--
130	45	316	190	--	--	85	4	--	--
131	--	--	609	26	--	--	5	--	--
132	--	--	594	14	--	5	27	--	--
133	--	57	513	--	--	21	49	--	--
134	77	207	307	--	--	11	38	--	--
135	25	327	239	20	--	29	--	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
136	71	233	258	60	--	18	--	--	--
137	103	--	--	491	--	6	40	--	--
138	12	107	351	145	--	25	--	--	--
139	--	126	382	79	--	29	24	--	--
140	--	95	266	--	--	127	34	--	118
141	24	--	553	43	--	--	20	--	--
142	--	40	447	83	--	70	--	--	--
143	36	90	486	--	--	4	24	--	--
144	110	279	208	--	--	43	--	--	--
145	120	374	100	--	--	29	17	--	--
146	119	36	380	49	--	36	20	--	--
147	169	315	86	34	--	--	36	--	--
148	79	177	346	--	--	38	--	--	--
149	77	282	41	163	--	37	40	--	--
150	--	--	587	38	--	15	--	--	--
151	147	181	227	42	--	--	43	--	--
152	176	96	54	314	--	--	--	--	--
153	124	302	146	--	20	4	44	--	--
154	130	231	57	187	--	--	35	--	--
155	73	172	261	122	--	--	12	--	--
156	105	254	243	--	--	--	38	--	--
157	137	336	77	90	--	--	--	--	--
158	234	314	70	--	--	--	22	--	--

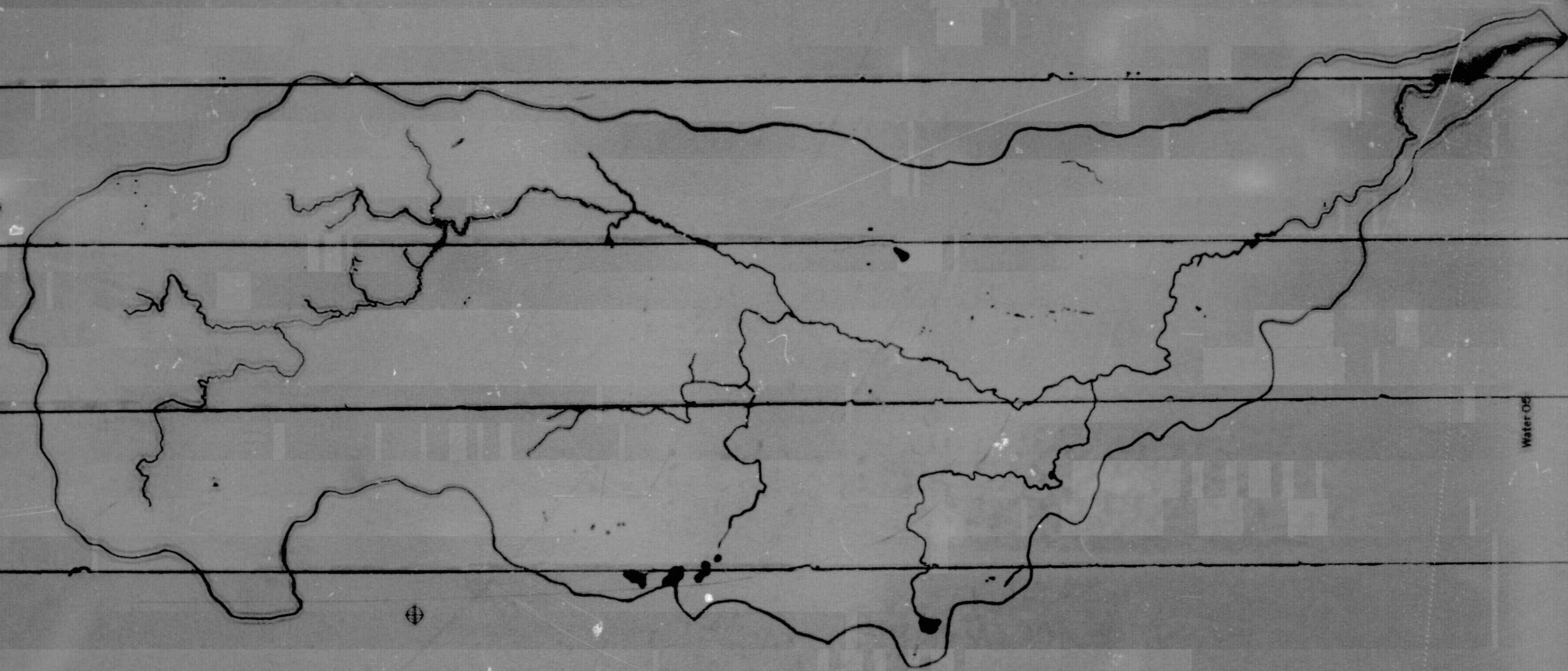
Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
159	53	54	--	533	--	--	--	--	--
160	77	248	--	315	--	--	--	--	--
161	--	107	--	104	--	--	16	413	--
162	98	100	--	113	--	--	17	312	--
163	181	118	--	307	--	--	--	34	--
164	212	43	385	--	--	--	--	--	--
165	160	254	217	--	--	9	--	--	--
166	172	139	329	--	--	--	--	--	--
167	133	173	261	--	--	32	41	--	--
168	361	255	--	24	--	--	--	--	--
169	154	105	--	--	--	15	--	366	--
170	114	317	199	--	--	--	10	--	--
171	149	23	--	252	--	--	--	216	--
172	--	20	406	214	--	--	--	--	--
173	--	--	335	305	--	--	--	--	--
174	189	244	191	16	--	--	--	--	--
175	99	155	383	--	--	3	--	--	--
176	86	330	221	--	--	--	3	--	--
177	186	328	78	19	--	--	29	--	--
178	67	227	2[illegible]0	--	--	--	56	--	--
179	141	266	185	--	--	18	30	--	--
180	153	328	159	--	--	--	--	--	--
181	166	339	89	--	--	--	46	--	--

Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
182	--	--	206	434	--	--	--	--	--
183	--	--	452	131	--	57	0	--	--
184	156	149	335	--	--	--	--	--	--
185	159	162	319	--	--	--	--	--	--
186	55	18	347	146	--	74	--	--	--
187	223	194	73	89	--	--	61	--	--
188	220	198	101	--	--	40	81	--	--
189	178	353	36	27	--	--	46	--	--
190	139	275	169	--	--	--	57	--	--
191	145	297	160	--	--	--	38	--	--
192	--	--	598	40	--	2	--	--	--
193	--	--	489	151	--	--	--	--	--
194	104	93	374	--	--	69	--	--	--
195	89	211	340	--	--	--	--	--	--
196	74	352	214	--	--	--	--	--	--
197	23	143	295	132	--	20	27	--	--
198	106	269	227	--	--	38	--	--	--
199	180	359	65	--	--	29	7	--	--
200	223	215	--	144	--	43	15	--	--
201	219	263	--	80	--	20	58	--	--
202	89	322	223	--	--	--	6	--	--
203	--	27	349	198	--	66	--	--	--
204	102	156	296	72	--	14	--	--	--

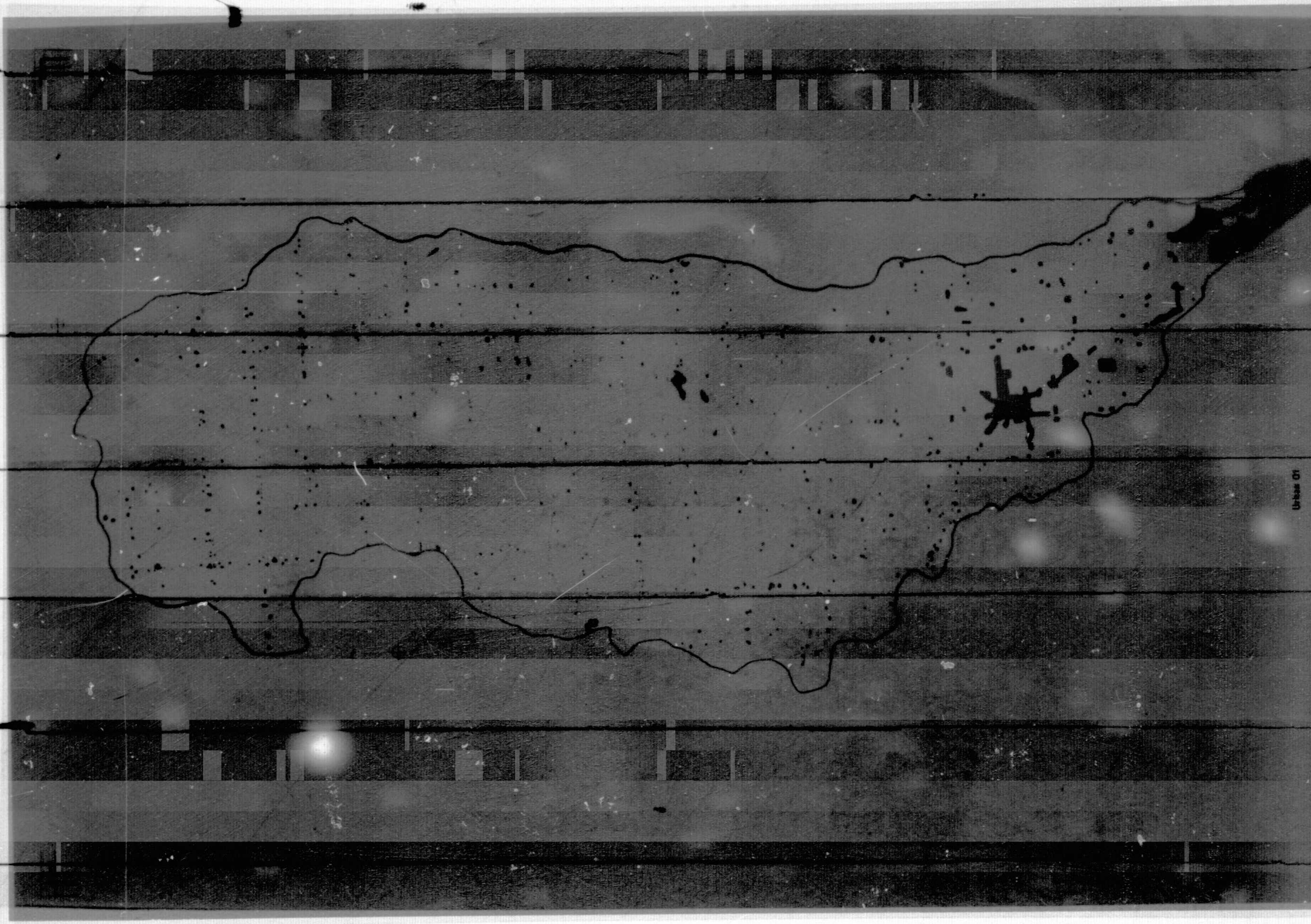
Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
205	78	212	326	--	--	24	--	--	--
206	102	190	98	204	--	23	23	--	--
207	112	140	86	250	--	--	52	--	--
208	75	62	--	152	--	--	--	351	--
209	149	255	--	191	--	36	9	--	--
210	--	88	--	117	--	--	--	--	435
211	--	--	528	72	--	--	40	--	--
212	--	--	174	466	--	--	--	--	--
213	205	216	219	--	--	--	--	--	--
214	75	340	--	161	--	19	45	--	--
215	139	189	35	277	--	--	--	--	--
216	47	104	--	445	--	--	44	--	--
217	132	82	76	160	--	35	21	134	--
218	--	--	144	--	258	238	--	--	--
219	103	97	--	415	--	25	--	--	--
220	131	392	117	--	--	--	--	--	--
221	138	359	48	--	--	--	95	--	--
222	54	--	65	521	--	--	--	--	--
223	--	--	--	24	--	--	11	208	397
224	--	24	616	--	--	--	--	--	--
225	180	306	99	--	--	12	43	--	--
226	124	57	72	148	83	85	71	--	--
227	156	247	33	71	88	--	45	--	--

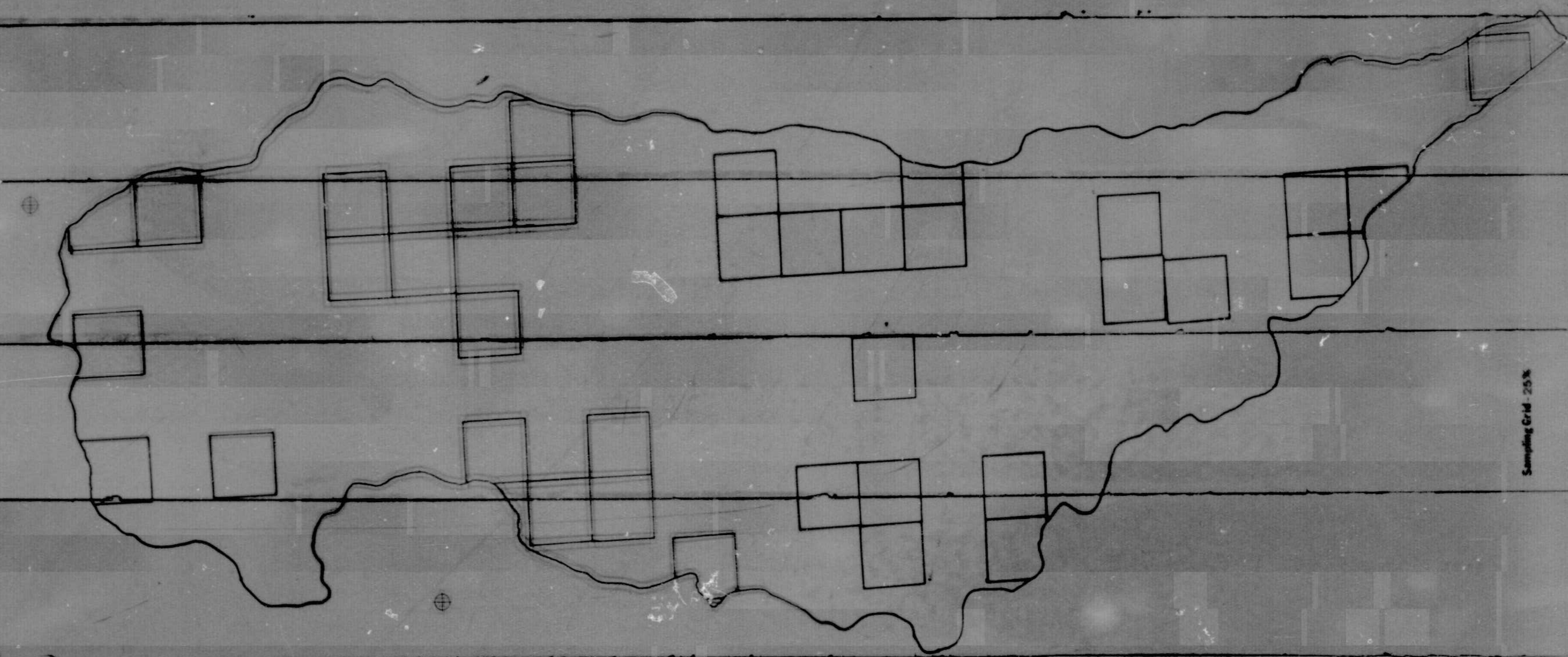
Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
228	19	134	260	166	--	--	61	--	--
229	128	259	191	--	--	--	62	--	--
230	38	49	--	52	--	--	11	490	--
231	367	166	--	58	--	--	49	--	--
232	59	--	--	--	543	38	--	--	--
233	36	--	604	--	--	--	--	--	--
234	128	183	273	--	--	--	56	--	--
235	114	285	211	--	--	20	10	--	--
236	177	323	--	140	--	--	--	--	--
237	95	58	54	69	324	40	--	--	--
238	--	70	502	17	--	--	51	--	--
239	143	--	408	--	--	18	71	--	--
240	255	81	--	18	--	59	--	227	--
241	289	275	--	46	--	15	--	15	--
242	323	83	--	181	--	53	--	--	--
243	128	--	--	371	--	--	--	--	141
244	37	--	517	--	--	37	49	--	--
245	93	309	177	--	--	42	19	--	--
246	143	346	141	--	--	--	10	--	--
247	61	361	126	--	--	17	75	--	--
248	137	423	49	--	--	--	31	--	--
249	23	--	445	--	--	100	72	--	--
250	59	294	234	--	--	--	53	--	--

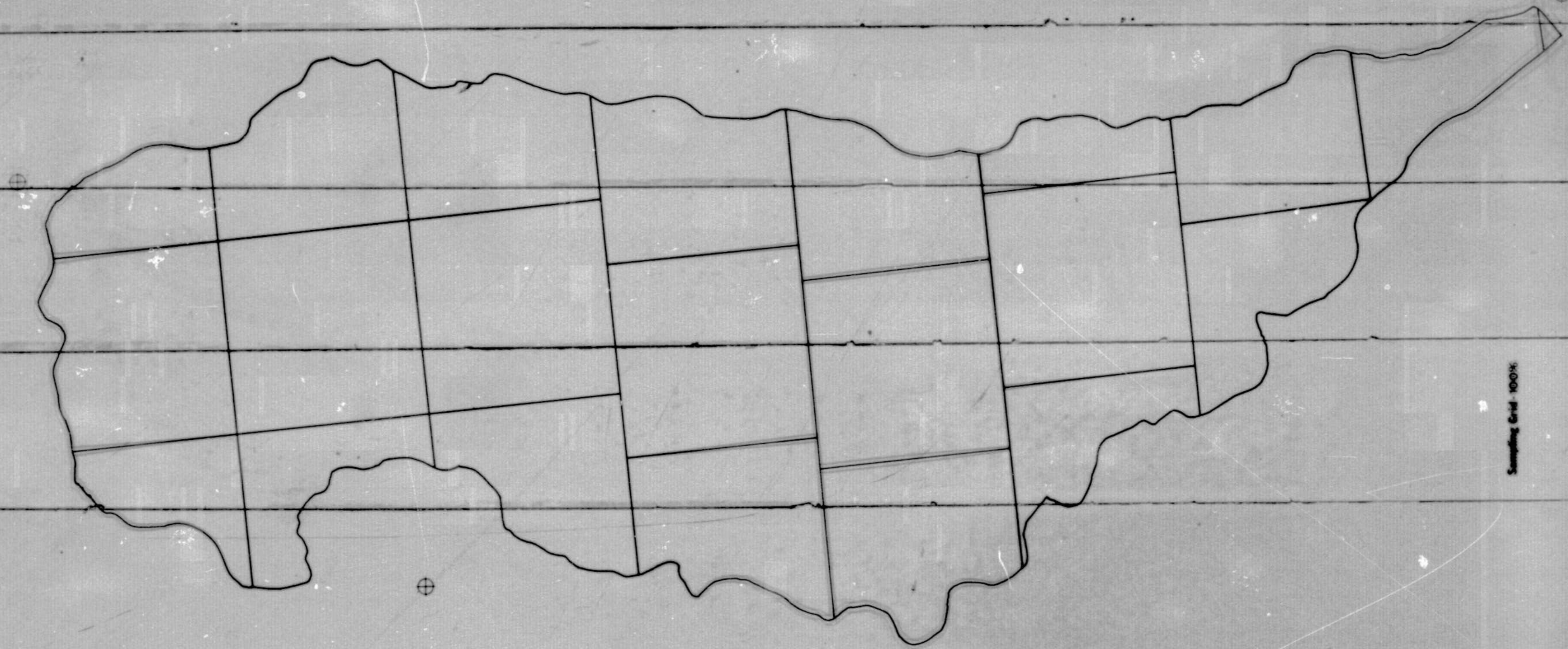
Sample No.	Agriculture Open (02-05)	Agriculture Closed (02-01)	Forest (04)	Wetland (06)	Urban (01)	Water (05)	Other	Clouds	Area Outside Watershed
251	156	360	106	--	--	11	7	--	--
252	74	253	274	--	--	--	39	--	--
Total	14065	27660	78763	19386	1551	4998	6182	2766	1429
Percentage of total watershed (155371 acres)	9	18	51	12	1	3	4	2	



Water 05




Sampling Grid - 25%



Sampling Grid - 100%

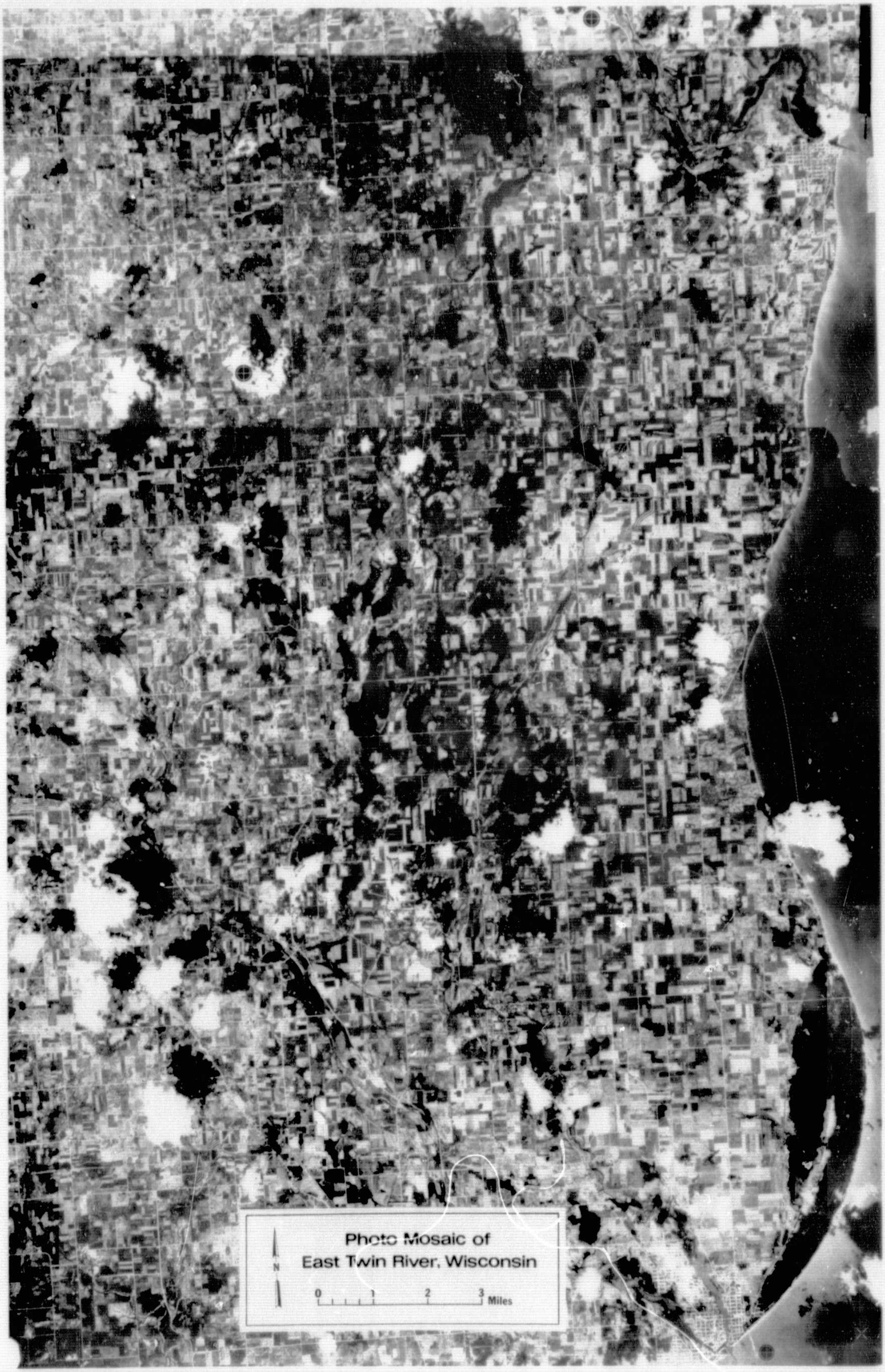
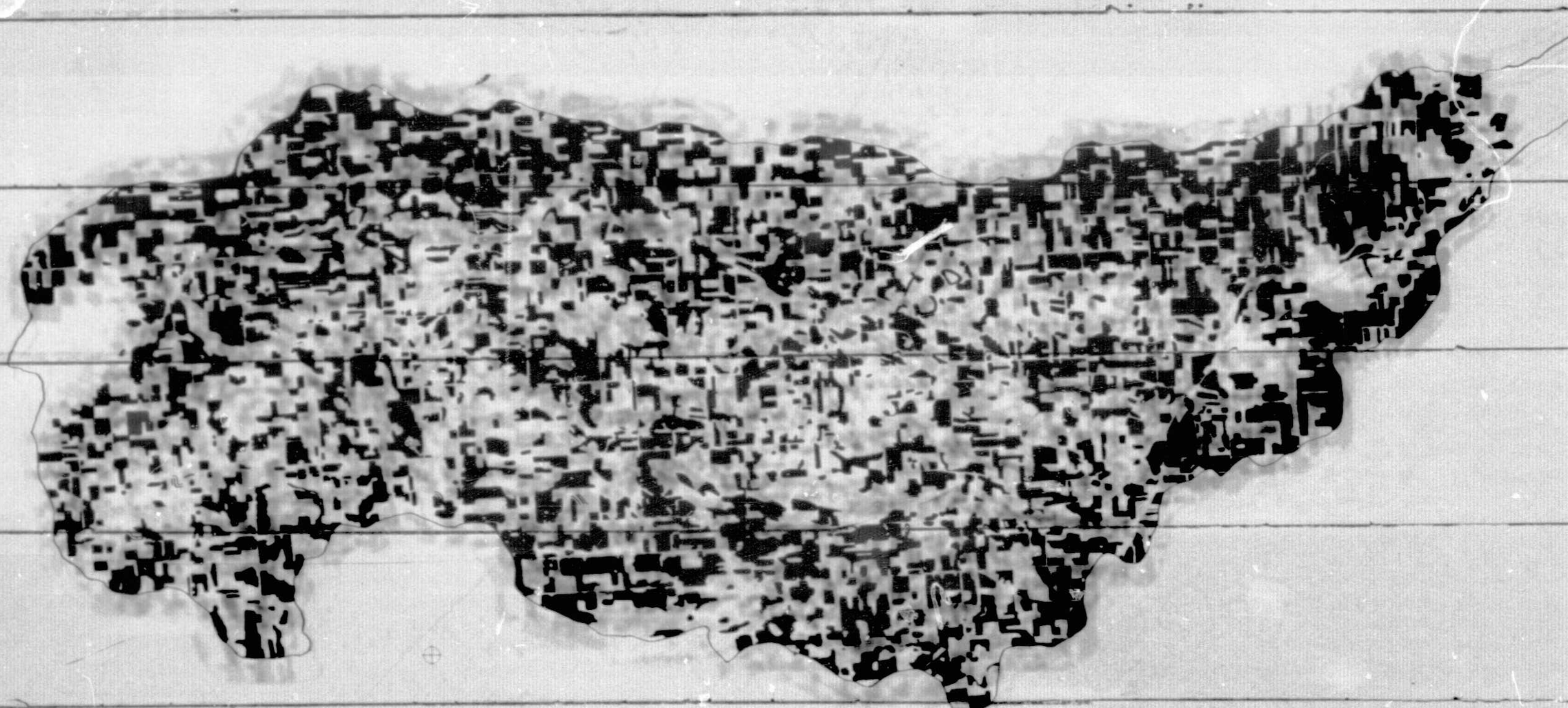


Photo Mosaic of
East Twin River, Wisconsin
N
0 1 2 3 Miles



Agriculture(open) 02 01-02